

NASA Earth Science Division, Applied Sciences Program

Health & Air Quality

Summary of Calendar Year 2012

The Health & Air Quality Applications area encourages the use of Earth observations in air quality management and public health, particularly involving environmental health and infectious diseases. The area also addresses effects of climate change on air quality and public health to support managers and ultimately people with health-related decision making. In 2012, the Health & Air Quality portfolio included 20 projects and feasibility studies along with the 19-member Air Quality Applied Sciences Team.

The most common technical issue in the portfolio in 2012 remained the final transfer of projects to sustainable operations. While some projects have performed admirably in this task, others still faced hurdles in completing this final step. The most common hurdle appeared to be more an issue of partner budget issues than partner capacity. However, overall the portfolio exceeded expectations on technical performance. In fact, the portfolio is on track for over 80 percent of its projects to increase by one Application Readiness Level (ARL) in FY 2013. Additionally, five projects are expected to achieve ARL 8 in FY 2013.

The portfolio continued to carry a high burden of uncosted funds in 2012. Associates worked diligently with principal investigators to uncover issues at their particular institutions. Many times this appeared to be an issue of “invoice lag” between NASA and the institution, with costed funds not showing on NASA accounts until long after invoices had been submitted by grantees.

Overall, the portfolio had a good track record for remaining on schedule in 2012, with limited no-cost extensions approved based on new opportunities or partner issues.

In general, the portfolio accomplished significant results and accomplishments in all areas in 2012, with a bright outlook for 2013. The following five projects were particularly noteworthy:

1. A health applications project to develop a repository of data specifically for decision making in malaria and meningitis control concluded in 2012. In collaboration with the International Research Institute for Climate and Society at Columbia University, the project team created online “rooms” for malaria and meningitis. They provide public health officials with dynamic maps and tools to create time series of disease status and relevant environmental factors. The maps and tools incorporate vegetation, land surface temperature, and other data products from MODIS and *Landsat*/ETM. The team also developed interfaces that link outputs from the repository to WHO and other public health platforms. To view the resources for meningitis and malaria control, visit <http://iridl.ldeo.columbia.edu/maproom/Health>.

2. A project to improve the performance of air quality management decision support tools achieved significant milestones. The project focuses on tools used in the process for development and evaluation of emission controls under provisions of the U.S. Clean Air Act. In 2012, the project team incorporated MODIS aerosol and *Aura*/OMI ozone data in the Community Multiscale Air Quality model, which states use in their planning to meet air quality standards. EPA and the Texas Commission on Environmental Quality are partners on this project; the commission generously provided complementary funding.
3. In early 2012, Health & Air Quality joined in the launch of the CDC Climate Change module within the National Environmental Public Health Tracking Network, a resource for policy makers and health professionals. The new module uses an NLDAS-based maximum temperature and maximum heat index provided by the applications area.
4. A decision-making tool that produces and distributes Naval Research Laboratory (NRL) real-time and historical analyses and forecasts of long range aerosol transport to Air Quality decision makers via Washington University's DataFed system reached significant milestones in 2012. The project made a concerted effort to support the assessment of potential Exceptional Event candidates for several states and EPA. In particular, the tools developed under this project were used to provide evidence that air quality exceedances over Nebraska and Kansas in October 2012 were caused by a dust storm generated by high winds and dry soil over the plains.
5. Significant progress was made in a project aimed at improving the nation's Air Quality Index (AQI) maps and products by introducing satellite PM estimates, thereby helping fill data gaps in areas with sparse *in situ* networks. These maps and products are disseminated through AirNow, a portal that provides the public with easy access to national air quality information. In fact, recent surveys show 75 percent to 80 percent of the public are aware of AQI and 50 percent report taking action based on it. In 2012, the project deployed the AirNow Satellite Data Processor (ASDP) modules and reduced relative errors in estimating surface PM_{2.5} from satellite data from 50 percent to 100 percent to less than 50 percent for most of North America. The project also established a real-time operational PM_{2.5} data feed at NOAA; however, this aspect continues to face uncertainty due to budget cuts at NOAA.

Detailed results on two other projects—improvements to the CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) system and enhanced decision making for hemorrhagic fever risk characterization in sub-Saharan Africa—can be found in the 2012 NASA Applied Sciences Annual Report.

The Health & Air Quality team conducted its annual review in partnership with the Naval War College, which does significant applied research on health effects of air quality, in

Rhode Island. This 2012 event was the first meeting with both the health and air quality projects together. The review consisted of an accounting of results and milestones met over the past year and, if the project was continuing, a look forward to plans for the coming year. Principal investigators also detailed any risks to schedule and/or intended milestones—and a plan on how to mitigate those risks, if any. Project risks could include technical risks/challenges (e.g., loss of satellite during project, significant technical hurdle), operations challenges/risks, management challenges/risks (e.g., partners don't focus on project as promised), or policy challenges/risk. PIs also included information on current budget—including costing data. Additionally, PIs justified their current ARL (from the August 2012 assessment). The 2013 annual review is planned for September in St. Paul, Minnesota. Presentations from the 2012 review can be found at the following link: http://weather.msfc.nasa.gov/conference/phconference_agenda_np.html.

The applications area presented and led sessions at meetings of the American Association for the Advancement of Science (AAAS), the American Thoracic Society, the Central States Air Resources Agencies (CenSARA), the American Geophysical Union (AGU), and the American Meteorological Society (AMS). The session at AAAS garnered widespread media attention, including international attention from media organizations in Denmark and Australia. The meeting with CenSARA was the first of its kind between NASA and this regional consortium. A major outcome of this meeting was an agreement to hold one of the 2014 AQUEST semi-annual reviews in a CenSARA state. Multiple sessions from the portfolio, as well as the Air Quality Applied Sciences Team (AQUEST), were held during the AGU Fall Meeting. Sessions at the AMS annual meeting in Austin were held as part of the 4th Conference on Environment and Health, of which NASA is a standing committee member. The success of these sessions led to meetings with AMS President, Dr. Marshall Shepherd, to highlight the Environment and Health focus area at the 2014 AMS Annual Meeting in Atlanta in coordination with entities such as The Weather Channel and the CDC.

John Haynes, program manager, presented a lecture on applications of Earth observations for health and air quality on April 17 at the Uniformed Services University of the Health Sciences, which is part of the Military Health System.

In June, the Organization for Economic Cooperation and Development (OECD) held a global Forum on Health hosted by the French space agency, CNES. This event was the fourth in a series of workshops on issues raised in the OECD report, "Future Global Shocks: Improving Risk Governance." By invitation, Haynes spoke at this event, which discussed the capacity of technology (including remote sensing) to monitor and warn for global threats, including threats to health such as pandemics.

Through the program's standing on the U.S. Global Change Research Program's Climate Change and Human Health Working Group (CCHHG), a community open forum was held in December 2012. This Open Forum was designed to facilitate discussion among research and application partners and key laboratories, observation networks, and modeling groups. It is planned that this forum will lead to a wider meeting in 2013 to discuss potential joint funding opportunities. The program also coordinated NASA's contribution on the CCHHG to MATCH, the Metadata Access Tool for Climate and Health. MATCH is planned as a publicly

accessible, online tool for researchers that offers centralized access to metadata—standardized contextual information—about thousands of government-held datasets related to health, the environment, and climate-science. MATCH is planned to launch in May 2013.

The program participated in the 4th Group on Earth Observations (GEO) Community of Practice for Health and Environment in July in Karlsruhe, Germany. This meeting provided a forum for the earth observing public health, medical and other interested communities to discuss current GEO Health Tasks, establish new partnerships, plan for future collaborations, exchange information about related activities, and inform GEO about progress and observing requirements. One of the primary outcomes of the meeting was completion of task sheets for each of the Health components in the new GEO work plan. NASA is a primary contributor to GEO tasks HE-01-C1: Air-borne Diseases, Air Quality and Aeroallergens and HE-01-C3: Vector-borne Diseases.

The program was integral to the success of the 2012 *NPP* Applications Workshop in Washington, D.C. This workshop's purpose was to update the Earth science and applications communities on *NPP*, review applications of data from *NPP* in four elements of the Applied Sciences Program, and provide an opportunity for community feedback to NASA on data products, data access and other user needs. The workshop's final report is posted online at http://geo.arc.nasa.gov/npp/suomi_summary.pdf. The next *NPP* Applications Workshop is tentatively planned for 2014. Additionally, the program co-organized a *GPM/GRACE/SMAP* applications workshop at USGS in October 2012 in coordination with the Water Resources Applications area.

In 2013, the Health & Air Quality Applications area plans to solicit proposals for feasibility studies and in-depth projects on innovative uses of Earth observations for infectious disease, environmental health, and air quality forecasting and planning. The applications area will be involved in the second phase of the DISCOVER-AQ airborne field campaign, as well as the Studies of Emissions, Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) campaign, especially through AQUEST. The area also plans to hold an AQUEST results workshop in June at the University of Maryland. In addition, it plans to expand its relationship with current and future relevant NASA satellite missions, as well as Earth Venture campaigns such as the recently awarded TEMPO mission.

NASA Air Quality Applied Sciences Team (AQAST)

AQAST connects air quality managers with atmospheric scientists and applications specialists to apply the latest knowledge and data. Team members conduct individual applied research projects and participate in ad hoc teams for rapid-response applications. AQAST meets twice a year to review progress and meet with managers from state, local, and regional air quality agencies to identify key needs for applications and specific opportunities to transfer their scientific knowledge.

AQAST held two team meetings in 2012. One meeting took place in June at the University of Wisconsin, Madison, addressing air quality issues in the upper Midwest. Representatives from the Lake Michigan Air Directors Consortium, Wisconsin Department of Natural Resources, Southeast Michigan Air Quality Study Group, and EPA Region 5 presented key issues facing their organizations and locales. In addition, the meeting assisted Environment Canada in determining the growth of nitrogen dioxide emissions using satellite observations over the Alberta oil sands. Team member Bryan Duncan reported on the dramatic decrease in sulfur dioxide and nitrogen dioxide emissions over the eastern United States during the past seven years as measured by *Aura*/OMI. AQAST member Greg Carmichael, University of Iowa, reported on his assistance in 2012 to Iowa City public health officials during a local landfill fire. He provided results from WRF air quality models to assist them in determining public health risks from the smoke plumes during weekend outdoor events.

AQAST also held a November 2012 meeting in Sacramento in partnership with the California Air Resources Board. Participants discussed current air quality management issues in California and western states, such as the need for central California to reduce emissions by 60 percent over the next several years to fulfill regulatory requirements. AQAST members identified opportunities to provide assistance regarding PM_{2.5} micron emissions, ozone emissions, modeling of complex terrain, and transboundary pollution (especially from Asia and Mexico). AQAST member Ed Hyer, Naval Research Laboratory (NRL), announced the transition to ESD's LANCE near real-time system of the NRL MODIS Level 3 Aerosol Optical Depth product. Additionally, AQAST unveiled the publication of a popular lenticular based on *Aura*/OMI observations detailing the change in CONUS NO₂ emissions since 2005.

AQAST announced that January 2013 would see the launch of controlled and agriculture burn forecasting for Iowa in partnership with the Iowa Department of Public Health. AQAST plans to hold its 2013 meeting in June in the mid-Atlantic region.

More details on AQAST can be found on the new website it launched in 2012, www.aqast.org.

Project Highlights

Project: Development of a Detection and Early Warning System for Malaria Risk in the Amazon

Principal investigator: Benjamin Zaitchik, Johns Hopkins University

Project year: 18-month feasibility study with no-cost extension, ending October 2013

Year-end ARL: N/A, feasibility study

Description:

This project seeks to establish the feasibility of implementing a malaria risk monitoring and early warning system for the Peruvian Amazon that draws on satellite data and NASA hydrological models for environmental predictors. Additional objective:

- Use the Peruvian Amazon as a test case for methods that could be applied across the Amazon and in other malaria-affected regions.

End users: Peruvian Ministry of Health; PRISMA, a health-oriented Peruvian NGO

Data sources, models, technology: *TRMM* Multisensor Precipitation Analysis, MODIS vegetation indices and land cover, *Landsat* imagery for high resolution land cover analysis, AMSR-E soil moisture estimates. Primary NASA modeling tool: Land Information System, which serves as the software platform for the land data assimilation system used in the malaria prediction model.

Major accomplishments in CY 2012:

- Implemented the Peruvian Amazon Frontier Land Data Assimilation System for fine-scale (1 km resolution) and regional scale (5 km resolution) analysis.
- Generated *Landsat* land cover and land cover change maps for the region of active road building around Iquitos, the largest city in the region.
- Completed work on a hierarchical Bayesian modeling system for predicting species-specific mosquito distribution as a function of land use and hydrometeorology.
- Generated a Poisson statistical model of malaria cases as a function of land cover, hydrometeorology, and demographic information.

Plans or expectations for 2013:

- Present project results at 2013 AMS Annual Meeting.
- Finalize the details of the Poisson malaria risk model.
- Complete three manuscripts.

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Project: Enhanced Forecasting of Mosquito-borne Disease Outbreaks Using AMSR-E

Principal investigator: Michael Wimberly, South Dakota State University

Project year: 2

Year-end ARL: N/A, feasibility study

Description:

To enhance the capabilities of an early warning system for West Nile virus (WNV), the project tests the performance of land surface parameters that have direct ecological relationships with mosquito populations and mosquito-borne disease risk.

End users: Sioux Falls Health Department; South Dakota Department of Health

Data sources, models, technology: AMSR-E, MODIS optical-infrared data, NLDAS

Major accomplishments in CY 2012:

- Published paper in *Remote Sensing of Environment*, finding that mosquito population models based on AMSR-E land surface parameters had better predictive capabilities than models based on *in situ* weather station data: Chuang et al., "Satellite microwave remote sensing for environmental modeling of mosquito population dynamics."
- Published paper in *PLOS One* documenting the use of optical-infrared data from MODIS (NDVI, land surface temperature, and actual ET) for regional modeling of the relative risk of WNV using historical surveillance data on human WNV cases and environmental indices: Chuang and Wimberly, "Remote sensing of climatic anomalies and West Nile virus incidence in the northern Great Plains of the United States."
- Used this model to successfully predict the reemergence of WNV in the northern Great Plains during the summer of 2012 and disseminated risk maps to public health decision makers in South Dakota.

Plans or expectations for 2013:

- Use data from NLDAS to analyze climatic determinants of WNV dynamics across the conterminous United States.
- Continue to make WNV risk forecasts for the northern Great Plains and validate the accuracy of these forecasts.
- Incorporate, if possible, land surface parameters derived from microwave radiometry into these models.

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Project: Integration of Airborne Aerosol Prediction Systems and Vegetation Phenology to Track Pollen for Asthma Alerts in Public Health Decision Support Systems

Principal investigator: Jeffrey Luvall, NASA Marshall Space Flight Center

Project year: 4

Year-end ARL: 6

Description:

Integrating satellite- and ground-based observations, the project aims to create a pollen forecasting and alert system for environmental public health tracking of asthma. The asthma alert system is especially aimed at those individual allergic to *Juniperus* pollen in New Mexico, Texas, and Oklahoma. The forecasting and dispersion model requires a thorough understanding of the pollination ecology of *Juniperus ashei*, *J. monosperma*, *J. scopulorum*, and *J. pinchotii*. Additional objectives:

- Utilize DREAM (Dust REgional Atmospheric Model), a verified model for atmospheric dust transport modeling using MODIS data products, to identify source regions and quantities of dust.
- Modify the DREAM model to incorporate pollen transport (PREAM).

End users: CDC; U.S. National Phenology Network; New Mexico Department of Health

Data sources, models, technology: DREAM; MODIS-derived phenology of *Juniperus* spp. communities (used to estimate pollen release); ground-based observational records of pollen release timing and quantities (used for verification)

Major accomplishments in CY 2012:

- Completed pollen sampling activities.
- Tracked phenology to identify pollen (male cones) formation and density.
- Refined pollen source masks for all Juniper communities.
- Conducted DREAM modeling.
- Modified SYRIS to accept PREAM output.
- Developed data products for EPHTN.

Plans or expectations for 2013:

- Operational prototype of PREAM: running three-hour intervals at 40 km resolution during the three *Juniperus* spp. pollen release periods.
- Refine pollen source masks.
- Refine MODIS identification of pollen release periods.
- Ongoing validation of PREAM outputs.
- Incorporate PREAM outputs (animated gifs) of pollen transport into SYRIS, EPHTN, and U.S. National Phenology Network.
- Projected ending ARL: 7 (April 2014).

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Project: Investigating the Potential Range Expansion of the Vector Mosquito *Aedes aegypti* in Mexico with NASA Earth Science Remote Sensing Results

Principal investigator: William Crosson, United States Research Association

Project year: 2 (final)

Year-end ARL: 5

Description:

To better inform public health decision making in Mexico, the project is using remote sensing data to examine the survival and abundance of the vector mosquito for dengue viruses. Additional objectives:

- Facilitate the investigation and modeling of the social, economic, environmental, and epidemiological factors that control the survival and abundance of the mosquito vector *Aedes aegypti*, the primary transmitter of dengue viruses.
- Employ this integrated modeling approach toward understanding the potential range of *Aedes aegypti* to expand toward heavily populated, high elevation areas such as Puebla and Mexico City under various climate change and socioeconomic scenarios.

End users: CDC; SERVIR; University of Veracruz, Xalapa

Data sources, models, technology: MODIS, NLDAS, EPA ground-level data

Major accomplishments in CY 2012:

- Conducted a training session at the University of Veracruz, Xalapa, “Introduction to SERVIR for decision making through the use of GIS and remote sensing” (March).
- Two USRA scientists and one post-doc colleague traveled to Puebla to participate in the field work component of the project (July). During their visit, the scientists assisted in sampling of pupae and adult *Aedes aegypti*. The focus of this year’s field campaign was on the higher elevation fringe habitat for *Aedes aegypti*.
- Developed a regression-based “first generation” *Aedes aegypti* “potential habitat” model using spatial data on the climate and elevation of central and southern Mexico.

Plans or expectations for 2013:

- Share, through SERVIR data portal, “potential habitat” model map, input data sets, and others describing vegetation and land surface temperature.
- Projected ending ARL: 5 (February 2013).

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Project: Linking NASA Environmental Data with a National Public Health Cohort Study to Enhance Public Health Decision Making

Principal investigator: Leslie Ain McClure, University of Alabama at Birmingham

Project year: 3 (final)

Year-end ARL: 8

Description:

Using a variety of Earth science data, the project is bolstering a key public health system, allowing disease specialists and public health professionals to better assess risks and protect the well-being of the public. Additional objectives:

- Characterize PM2.5, solar insolation, and land surface temperature using remote sensing and other data.
- Link these data to participants in the REasons for Geographic And Racial Differences in Stroke (REGARDS) study, in order to determine the role these exposures play in the development of stroke and cognitive decline, and to determine their relationship with stroke risk factors.
- Disseminate the data sets to end users, such as public health professionals, for decision making through the CDC WONDER portal.

End users: CDC, public health professionals, state and local health departments

Data sources, models, technology: MODIS, NLDAS, EPA ground-level data

Major accomplishments in CY 2012:

- Examined relationship between PM2.5 and incident impairment among REGARDS participants (manuscript drafted).
- Examined the relationship between solar insolation and stroke risk factors (manuscript drafted).
- Examined the relationship between PM2.5 and stroke; presented poster at the American Heart Association International Stroke Conference.
- Delivered MODIS land surface temperature data to CDC WONDER.
- Delivered NLDAS daily sunlight data to CDC WONDER.
- Delivered PM2.5 data set to CDC WONDER.

Plans or expectations for 2013:

- Complete additional analyses on the association between PM2.5 and stroke; submit manuscript.
- Assess the association between PM2.5 and stroke risk factors.
- Conduct maintenance on the data sets in CDC WONDER.
- Projected ending ARL: 9 (September 2013).

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Project: Modeling Global Influenza Risks Using NASA Data

Principal investigator: Richard Kiang, NASA Goddard Space Flight Center

Project year: 2

Year-end ARL: N/A, feasibility study

Description:

To support public health organizations worldwide, the project is assessing the feasibility of modeling influenza risks using satellite- and ground-based observations. Additional objectives:

- Examine how influenza circulation is affected by meteorological, environmental, or other factors at major population centers around the world.
- Develop predictive models if there is significant dependency on these factors.
- Share results with public health stakeholders to strengthen their influenza surveillance and response capabilities.

End users: CDC; WHO; public health agencies of Germany, Guatemala, Israel, Kenya, Panama, El Salvador, Slovenia, Spain, etc.

Data sources, models, technology: *TRMM* precipitation; MODIS land surface temperature; GLDAS precipitation, temperature, specific humidity; ground stations: min/max/mean temperature, relative humidity, dew point, solar irradiance, etc.

Major accomplishments in CY 2012:

- Negotiated and obtained influenza data from Germany, Guatemala, Israel, Kenya, Norway, Panama, El Salvador, Slovenia, and Spain.
- Processed influenza data from sentinel locations into suitable forms for analysis and modeling.
- Processed Earth observation data to a spatio-temporal resolution compatible with influenza data.
- Analyzed/derived influenza predictive models for Guatemala, Panama, and El Salvador.
- Analyzed influenza data for regions in countries of WHO Regional Office for Europe.
- Presented at ASTMH Annual Meeting (November): Soebiyanto et al., "Role of Temperature, Humidity, and Rainfall on Influenza Transmission in Guatemala, El Salvador, and Panama."
- Published conference proceeding: Kiang and Soebiyanto, "Mapping the risks of malaria, dengue and influenza using satellite data," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, ISPRS Congress (August-September).
- Contributed book chapter: Soebiyanto and Kiang, Climate and influenza: a review, in Morain and Budge, eds., *Environmental Tracking for Public Health Surveillance*.

Plans or expectations for 2013:

- Obtain additional influenza data from WHO and European Center for Disease Prevention and Control.

- Complete predictive modeling for regions in countries such as Germany, Israel, Kenya, Slovenia, Spain, etc.
- Complete manuscripts on project outcomes.

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Project: Predicting Zoonotic Hemorrhagic Fever Events in Sub-Saharan Africa Using NASA Earth Science Data

Principal investigator: Jorge Pinzon, Science Systems and Applications, Inc.

Project year: 4 (final)

Year-end ARL: 6 (final)

Description:

A project used satellite data to improve the prediction of infectious disease outbreaks, helping public health professionals to be better prepared and positioned to save lives.

Additional objectives:

- Enhance and strengthen the AFHSC-GEIS multidisciplinary efforts to build a sustainable global capacity for surveillance and response to emerging zoonoses (in sub-Saharan Africa), in particular surveillance and response to Ebola, Marburg, and Rift Valley hemorrhagic fever events based on remote-sensing and ecologic-niche modeling.
- Contribute space imaging capabilities for global surveillance and response networking, complementing AFHSC-GEIS operations and existing international (WHO, FAO) and national surveillance systems, using early warning and monitoring risk maps data.
- Provide practicable information to AFHSC-GEIS end users (U.S. forces, military-associated populations, and the global public health community) through a versatile Web mapping service.

End users: WHO, FAO, DoD, ministries of health and agriculture

Data sources, models, technology: MODIS surface temperature data, NASA NDVI vegetation index data from NOAA's AVHRR, TRMM and GPCP precipitation data

Major accomplishments in CY 2012:

- Improved risk classification schemes by integrating disease, vector, and animal data with climatic indicators into global risk maps.
- Improved calibration of real-time and archived environmental indicators of zoonotic activity in sub-Saharan Africa and ensured data continuity.
- Adjusted environmental monitoring and risk maps for integration of risk maps and satellite data into versatile Web mapping service to provide a platform for future expansion to global surveillance.
- Contributed to chapters 2, 5, and 6 of Morain and Budge, eds., *Environmental Tracking for Public Health Surveillance*.

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Project: Feasibility Study of Satellite-assisted Detection and Forecasting of Oyster Norovirus Outbreak

Principal investigator: Zhiqiang Deng, Louisiana State University

Project year: 2

Year-end ARL: N/A, feasibility study

Description:

In collaboration with Louisiana public health decision makers, the project seeks to demonstrate the feasibility of utilizing MODIS data in predicting oyster norovirus outbreaks.

End users: Molluscan Shellfish Program of Louisiana Department of Health and Hospitals; Infectious Disease Epidemiology Section of Louisiana Office of Public Health

Data sources, models, technology: MODIS (*Terra* and *Aqua*)

Major accomplishments in CY 2012:

- Collaborated with primary end users.
- Published paper in *Marine Environmental Research*, 80: Wang and Deng, "Detection and forecasting of oyster norovirus outbreaks."
- Predicted correctly the latest norovirus outbreak on December 12, 2012, in Louisiana Oyster Harvesting Area 30 (<http://www.dhh.louisiana.gov/index.cfm/newsroom/detail/2732>). Local, national, and international media featured this accomplishment, e.g., http://www.geospatialworld.net/News/View.aspx?ID=24885_Article.

Plans or expectations for 2013:

- Collect more data on oyster norovirus outbreaks.
- Test the model with the additional data.
- Publish manuscripts.

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Project: Internet-based Heat Evaluation and Assessment Tool (I-HEAT)

Principal investigator: Susan Maxwell, BioMedware

Project year: 2 (final)

Year-end ARL: N/A, feasibility study

Description:

The project examined the feasibility of providing health professionals with an advanced geospatial Web-based system for preparing and responding to emergency heat events, developing mitigation strategies, and educating the public. Additional objectives:

- Design, implement, and evaluate the prototype I-HEAT software and assessed its feasibility using focus groups comprised of end users and stakeholders.
- Link data from *Landsat 5* and NDVI with high resolution street-level mapping and Census data to identify local populations at-risk from adverse heat-related health events at the residential level.

End users: Michigan Department of Environmental Quality; Michigan Department of Community Health

Data sources, models, technology: WELD/*Landsat*, NDVI

Major accomplishments in CY 2012:

- Completed implementation of the I-HEAT prototype. Conducted pilot study of Detroit. Integrated WELD/*Landsat* (temperature and vegetation) and demographic/socioeconomic/health that enables identification of at-risk populations.
- Completed I-HEAT end user evaluation. Conducted user survey as part of end user hands-on testing at workshop convened in Detroit. Compared results against baseline data from CDC study.
- Completed the feasibility assessment report, including system configuration, quantitative and qualitative enhancements to decision support activity, major problems encountered/resolved, lessons learned, recommendations, and remaining issues for sustained use of WELD/*Landsat* in decision-making activity.
- Made nine conference presentations; conducted one end user workshop; prepared two papers for publication.
- Posted the prototype I-HEAT software on the BioMedware website:
<http://www.biomedware.com/I-Heat/IHeatViewer.html>.
- Posted the publications, reports, and other deliverables at
<http://www.biomedware.com/?module=Page&SID=i-heat>.

Plans or expectations for 2013:

- Project is complete: demonstrated feasibility, and there is a high level of interest from end users.
- Look for funding to fully build out the technology for sites across the United States.

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Project: Monitoring and Forecasting Cyanobacterial Blooms for Public Health Protection and Response

Principal investigator: Richard Stumpf, NOAA

Project year: 4

Year-end ARL: 6-8

Description:

Incorporating satellite data and models, the project is developing decision support tools for environmental and public health decision makers to address algal blooms. Additional objectives:

- Characterize algal blooms for public health and environmental risk based on satellite ocean color (NASA and ESA), develop early warning either seasonally (from USGS and state river flow and nutrient data), or daily using NOAA transport models, and weather observations, and combine with other field observations.
- Evaluate and implement robust methods for bloom detection and quantification that can be applied in many regions and under severe limitations of atmospheric correction.
- Disseminate forecasts and useful satellite data to health and environmental agencies through simple distribution systems (bulletins, GIS compatible imagery).

End users: EPA; CDC; Ohio Environmental Protection Agency; Maryland Department of Natural Resources; Florida Department of Health; St. Johns River Water Management District (Florida)

Data sources, models, technology: MODIS, NOAA transport models, USGS data

Major accomplishments in CY 2012:

- Delivered first forecast of severity of seasonal cyanobacterial bloom for Lake Erie. Presented at press event at Ohio State University Stone Laboratory on Lake Erie. In the fall, Ohio Sea Grant determined that it had been accurate.
- Issued 19 weekly bulletins of location and forecast of bloom in Lake Erie: 535 subscribers with various health and environmental agencies.
- Issued 18 health bulletins for Florida lakes: 107 subscribers with health and environmental agencies.
- Established an online tracking module for documenting cyanobacterial blooms in Florida through the Florida Department of Health.
- Published climatological analysis of cyanobacterial blooms in Lake Erie in *PLOS One*, which resulted in the model for an annual forecast of severity.
- Published paper on cyanobacteria forecast system in *Journal of Great Lakes Research*.
- Hosted Webinar for the EPA Great Lakes National Program Office Work Group on near-shore/nonpoint source pollutants.
- Conducted some user training and prepared initial user documentation.

- Supported Ohio Environmental Protection Agency, Maryland Department of Natural Resources, Florida Department of Health, and St. Johns River Water Management District (Florida) in planning for and responding to algal blooms.
- Assisted EPA in development of an EPA internal project to develop a smartphone distribution method for satellite products to managers.

Plans or expectations for 2013:

- Create seasonal forecast for Lake Erie for 2013.
- Issue weekly bulletins of bloom severity and forecast position for Lake Erie from June until end of bloom.
- Draft paper on use of MODIS data to substitute for MERIS in locating blooms.
- Draft paper on biomass estimation for the indices used in order to support needs of several state agencies (Maryland and Florida), algorithms that would apply to future sensors, including *Sentinel-3/OLCI*, and *PACE*.
- Issue weekly bulletins of bloom presence in Florida inland waters.
- Present at the Biennial National Harmful Algal Bloom Symposium.
- Collaborate with EPA, USGS, and state agencies to expand bloom detection methods to other areas.
- Conduct workshops in Ohio and Florida on bloom monitoring.

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Project: Influence of Land Use and Precipitation on Regional Hydrology and Public Health

Principal investigator: Charles Tilburg, University of New England

Project year: 3 (final)

Year-end ARL: N/A, feasibility study

Description:

The project demonstrated the use of a relatively simple regression model, with satellite-derived precipitation observations to predict reduced water quality events within coastal waters.

End users: Maine State Planning Office; Maine Department of Marine Resources

Data sources, models, technology: *TRMM* Microwave Imager (TMI)

Major accomplishments in CY 2012:

- Used satellite derived precipitation (TMI) data to forecast reduced water quality events in the coastal waters of Maine.
- Demonstrated that the simple model can be expanded to larger coastal regions.
- Provided stipends and projects for two undergraduate students
- Provided data for outreach to seven local schools.

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Project: Improving Decision-making Activities for Malaria and Meningitis Risk Mapping: Integration of NASA Products/Platforms (SERVIR) and WHO Open Health

Principal investigator: Pietro Ceccato, International Research Institute for Climate and Society, Earth Institute, Columbia University

Project year: 18-month study

Year-end ARL: N/A, not required

Description:

To support public health decision makers worldwide, the project developed a Web-based platform with malaria and meningitis products. The Extreme Heat Vulnerability Index (EHVI) made significant improvements to the model, and is now incorporating neural network analysis and a Web-based decision support interface system.

End users: WHO; ministries of health; Meningitis Environmental Risk Information Technologies (MERIT) at WHO and SERVIR

Data sources, models, technology: MODIS LST and *Landsat* Enhanced Thematic Mapper (ETM), currently exploring downscaling MODIS to *Landsat* ETM+ and TM resolutions

Major accomplishments in CY 2012:

- Developed a repository of data specifically relevant for decision making in malaria and meningitis control.
- Developed online “map rooms” for malaria and meningitis to provide dynamic maps and tools to create time series of disease status and relevant environmental factors.
- Developed interfaces to link outputs from data library to platforms used by the health community (Open Health) and wider public (NASA SERVIR and Google Earth).
- Reconstructed map room tools to be available as layers in NASA SERVIR, Google Earth, and WHO Open Health.
- Created new Malaria Map Room containing rainfall estimates and tools to analyze the data; MODIS vegetation products at 250 m spatial resolution; temperature map based on MODIS LST during the night as an approximation of minimum air temperature; MODIS LST during the day; new reconstructed MODIS maximum air temperature with associated tool to compare product with maximum air temperature measured in stations; vectorial capacity model; African country-average CMAP Weighted Anomaly Standardized Precipitation (WASP) with selectable baseline country; and seasonal climatic suitability for malaria transmission.

* * *

Project: Using NASA Data and Models to Improve Heat Watch/Warning Systems for Decision Support

Principal investigator: Daniel Johnson, Indiana University

Project year: 3

Year-end ARL: 6

Description:

The project seeks to develop a spatially specific warning system for extreme heat events, for the cities of Dayton (Ohio), Philadelphia, and Phoenix. Additional objectives:

- Incorporate data from a variety of remote sensing platforms (MODIS, *Landsat*), the U.S. Census Bureau, and mortality statistics from respective agencies.
- Integrate assimilated data into a forecast that provides for the identification of the most vulnerable locations in each locale during episodes of extreme heat.

End users: NWS; local health and fire departments and emergency management agencies

Data sources, models, technology: MODIS LST and *Landsat* Enhanced Thematic Mapper (ETM), currently exploring downscaling MODIS to *Landsat* ETM+ and TM resolutions

Major accomplishments in CY 2012:

- Incorporated Neural Network Analysis to improve analysis and future automation of process.
- Improved Web-based spatial decision support system.
- Incorporated Census 2010 data; identified changed variable relationships to older data.
- Presented project results at AGU Fall Meeting.
- Began downscale of MODIS data for inclusion into the model.
- Published paper in *Applied Geography*: Johnson et al., "Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data."

Plans or expectations for 2013:

- Continue work on MODIS downscaling for daily guidance in each city.
- Explore new cities that would be very good test areas for spatial expansion of the system (Indianapolis, Chicago have already been identified; NYC, Oklahoma City are future possibilities).
- Explore expansion spatially to statewide system.
- Complete project including no-cost extension.
- Projected ending ARL: 7 or 8 (May 2013).

* * *

Project: Enhancing Environmental Public Health Tracking with Satellite-driven PM2.5 Exposure Modeling and Epidemiology

Principal investigator: Yang Liu, Emory University

Project year: 3

Year-end ARL: 7

Description:

The project is using Earth observation and models to extend the spatial coverage of the PM2.5 indicators in the CDC Tracking Network. Additional objectives:

- Provide timely estimates of county-level PM2.5 health indicators.
- Evaluate satellite PM2.5 estimates as an alternative exposure data source in environmental epidemiologic studies.

End users: CDC

Data sources, models, technology: MISR, MODIS and GOES aerosol products, NLDAS meteorological parameters, NLCD land use classifications

Major accomplishments in CY 2012:

- Developed a two-stage LME+GWR modeling system to predict PM2.5 concentrations in the southeastern United States for 2001-2007. Submitted manuscript to *Remote Sensing of Environment*.
- Delivered model outputs to CDC Tracking for evaluation and creation of Tracking-format data tables.
- Evaluated two techniques for merging GOES and MODIS AOD measurements to improve data quality and spatial coverage. Submitted manuscript to *Geocarto International*.
- Developed a Bayesian spatial statistical downscaler mode to predicted daily PM2.5 levels with complete coverage in Georgia. Submitted manuscript to *Journal of Exposure Science and Environmental Epidemiology*.
- Presented research findings at AGU Fall Meeting and ISES Annual Meeting.

Plans or expectations for 2013:

- Develop models to address missing data issue related to satellite prediction.
- Continue the application of satellite data in environmental epidemiological models.
- Continue to work with Tracking to bring satellite data to the national public portal.

* * *

Project: Using NASA Satellite Aerosol Optical Depth Data to Create Representative PM2.5 Fields for Use in Human Health and Epidemiology Studies in Support of State and National Environmental Public Health Tracking Programs

Principal investigator: Amy Huff, Pennsylvania State University

Project year: 18-month feasibility study

Description:

The project examined the use of Earth observations and modeling to support state and national public health tracking. Additional objectives:

- Combine ambient fine particulate matter (PM2.5) concentration information, NASA satellite AOD data, and the CMAQ model using a statistical hierarchical Bayesian model (HBM) to make a single data set for use in health and epidemiological studies. The addition of AOD data are expected to create more temporally and spatially representative PM2.5 concentration fields compared with the current approach of using only monitor data and/or CMAQ model output.
- Focus on the Baltimore and New York City regions for 2004-2006.

End users: National Environmental Public Health Tracking Network; Maryland Environmental Public Health Tracking Program; EPA Advanced Monitoring Initiative for the Baltimore PM2.5 Community of Practice

Data sources, models, technology: PM2.5 concentration data from ground-based monitors, NASA AOD data, CMAQ model

Major accomplishments in 2012:

- Prepared PM2.5 data sets for input to HBM.
- Generated combined data sets using the Battelle/U.S. EPA statistical hierarchical Bayesian model (HBM).
- Collaborated with the New York State Department of Health; conducted an initial statistical analysis of the PM2.5 combined data sets and health outcome data sets for the New York City study area.
- Presented project results to date at the AGU Fall Meeting.

Plans or expectations for 2013:

- Continue analysis of combined PM2.5 and health outcome data sets in the New York City study area, focusing on correlations with asthma visits to the emergency department and hospitalizations.
- Collaborate with the Maryland Department of Health and Mental Hygiene; conduct a statistical analysis of the PM2.5 combined data sets and health outcome data sets in the Baltimore study area, focusing on correlations with asthma visits to the emergency department/hospitalizations and acute myocardial infarction hospitalizations.
- Provide three end user public health organizations PM2.5 concentration data sets if addition of AOD to the combined PM2.5 data sets shows added value.

* * *

Project: Improved Estimation of Air Quality Impacts of Wildfires at Ambient Air Quality Monitors Using Grid-based Air Quality Models

Principal investigator: Robert Chatfield, NASA Ames Research Center

Project year: 1 (final)

Year-end ARL: 4 (final)

Description:

This project incorporates data from multiple sources to help the San Joaquin Valleywide Air Pollutions Study Agency determine the effect of wildfires on ozone concentrations measured by ground-based ambient ozone monitors. Additional objectives:

- Use photochemical models run by the California Air Resources Board (Cal-ARB) to find out the influence of wildfire smoke on measured concentrations. Results of such a model can support the finding that a certain wildfire has contributed to an “exceptional event” in the regulatory context.
- Provide the following components to add to the basic model: locations, speciation and transport of emissions, assessment of the intensity of fuel consumption, and model assessment.

End users: California Air Resources Board (Cal-ARB), San Joaquin Valleywide Air Pollutions Study Agency

Data sources, models, technology: MODIS fire counts and land use; ARCTAS *in situ*; remote sensing from NASA’s DC-8 aircraft

Major accomplishments in CY 2012:

- Implemented Space Act agreement with Cal-ARB to study biomass burning effects on air quality emphasizing NASA’s “ARCTAS” California study of June 2008.
- Provided state-of-the-sciences reviews on biomass burning source strengths, compounds emitted, and plume lofting.
- Provided comparison of *in situ* aircraft data and (a first for Cal-ARB) ozone and smoke above and below the sampling aircraft (biomass-burning tracer based on LiDAR).
- Submitted paper to *Atmospheric Environment*: “Attribution of multiple VOC and NO_x emission sources including fire controlling O₃ production in California.”
- Presented results to Cal-ARB and at AGU Fall Meeting.
- Identified the “missing sulfur source” sought by Cal-ARB not identified by analysis of large NOAA effort in Los Angeles 2010 (“CalNEX”) or previous cursory analyses of NASA 2008 data.

Plans or expectations for 2013:

- Meet with Cal-ARB in February regarding anticipated nine-month study of greenhouse gas emissions.
- Investigate nitrogen compounds in DISCOVER-AQ 2013.

- Discuss with Cal-ARB how much future simulation work it wants to undertake.
- Projected ending ARL: 7 (March 2013).

* * *

Project: Linking NASA Satellite Data and Science to Enhance Fire Emissions within the EPA's National Emissions Inventory: Developing Agricultural/Rangeland Fire Emissions Estimates, Connecting Models to Plume Injection Height Data, and Verifying Modeled Emissions Estimates

Principal investigator: Amber J. Soja, National Institute of Aerospace/NASA Langley Research Center

Project year: 4 (final)

Year-end ARL: 7

Description:

Using remote sensing and *in situ* observations in collaboration with EPA, the project is developing unique products to enhance the existing National Emissions Inventory (NEI) and Community Multiscale Air Quality (CMAQ) model, thereby working to improve human health and the environment. Additional objectives:

- Use NASA science and data to enhance an existing algorithm that estimates area burned and fire emissions in poorly represented agricultural and rangelands, and synthesize cropland and rangeland fire research into a format usable by the existing Wildland Fire Emissions Information System (WFEIS).
- Analyze Cloud Aerosol LiDAR Orthogonal Polarization (CALIOP) data to build a fire plume injection height database that links fire behavior and fire weather to plume rise, to improve injection height within the NEI and CMAQ model simulations.

End users: EPA, state air quality offices

Data sources, models, technology: NEI, CMAQ, CALIOP, MISR

Major accomplishments in CY 2012:

- Organized and chaired a biomass burning session and a biomass burning expert panel at the EPA's Emissions Inventory Conference (August).
- Compared and contrasted numerous cropland emissions databases, providing confidence in the best data available and also as a means of benchmarking the product for improvement of the National Fire Emissions Inventory to support the implementation of geospatial data and models in the EPA's NEI.
- Delivered both state- and county-level cropland burned area emissions estimates for the contiguous United States to the EPA Air Quality Analysis Group/Office of Air Quality Planning and Standards.

- Several states opted to use the emissions estimates generated during this project in their NEI reporting.
- Validated initial CALIOP plume height results with coincident MISR data; developed preliminary mean statistics.
- Completed the development, mapping, and integration of the 2009 and 2010 cropland fuels into the main fuels map used in WFEIS.
- Presented “Using satellite data to quantify cropland burning and related emissions in the contiguous United States: Lessons learned,” International Emission Inventory Conference, Tampa, Florida.
- Published article in *Atmospheric Environment*, 63: McCarty et al., “Multi-year black carbon emissions from cropland burning in the Russian Federation.”

Plans or expectations for 2013:

- Complete the analysis of selected cases that benchmark CALIOP plume height data within CMAQ; submit two manuscripts for publication.
- Develop area burned and emissions estimates using NASA satellite data and science in rangelands.
- Projected ending ARL: 8 (September 2013).

* * *

Project: NASA and NAAPS Products for Air Quality Decision Making

Principal investigator: Douglas Westphal, Naval Research Laboratory

Project year: 3 (final)

Year-end ARL: 7

Description:

The project integrates multiple Earth observations to produce real-time and historical analyses and forecasts of the impact of long range transport on U.S. air quality. Additional objectives:

- Port analyses to the Visibility Information Exchange Web System and the Federated Data System (DataFed).
- Distribute data for decision making associated with the Regional Haze Rule, and Exceptional Event.

End users: EPA, state air quality offices

Data sources, models, technology: MODIS radiances, MODIS and *GOES* fires, MODIS, MISR, and AVHRR AOD, CALIOP layer boundaries and extinction, TOMS AI

Major accomplishments in CY 2012:

- Transferred NAAPS data to Washington University on a daily basis; backfilled to 2007.

- Harmonized NAAPS data products with the DataFed service-oriented data system.
- Resolved issues with formatting, routine data transfer, decoding as well as differences in operating systems.
- Focused on interaction with application clients, including researchers at NOAA as well as users at the EPA and several state air quality offices for Exceptional Event analysis and scientific studies.
- Presented project results at AAAR Annual Conference, AWMA Visibility and Air Pollution Meeting, and AGU Fall Meeting.

Plans or expectations for 2013:

- Use NAAPS data for initial and boundary conditions for regional AQ models.
- Projected ending ARL: 7 (September 2013).

* * *

Project: Improve Operational AQI Maps in AirNow by Fusing NASA Satellite-estimated PM2.5 with AirNow Observations

Principal investigator: Phillip Dickerson, Environmental Protection Agency

Project year: 4 (final)

Year-end ARL: 8

Description:

The project aims to improve AirNow's Air Quality Index (AQI) maps and products by introducing satellite PM estimates, thereby helping fill data gaps in areas with sparse *in situ* networks.

End users: air quality forecasters, researchers, emergency response personnel

Data sources, models, technology: MODIS (*Terra* and *Aqua*) AOD

Major accomplishments in CY 2012:

- Deployed the AirNow Satellite Data Processor (ASDP) modules at AirNow's Data Management Center.
- Selected data sources and determined weighting and uncertainty for data fusion.
- Implemented and tested data fusion.
- Reduced relative errors in estimating surface PM2.5 from satellite data from 50%-100% to < 50% for most of North America and eliminated the need for an online calculation of the AOD/PM2.5 ratio.
- Established a real-time operational PM2.5 data feed at NOAA.
- Created a sub-committee of AirNow stakeholders to evaluate the products, conducted evaluation and harvested multiple case studies.
- Developed a project website: asdp.airnowtech.org.

- Began economic evaluation design to determine benefits of AirNow and the addition of NASA satellite data.

Plans or expectations for 2013:

- Form ASDP task force to complete more in-depth review of the utility of ASDP products; collect more case studies.
- Complete socioeconomic evaluation.
- Conclude face-to-face interviews with state, local, EPA regional public health officials.
- Complete economic evaluation of impact of ASDP.
- Explore transitioning to an operational-status data feed from NOAA, as current data feed is in research environment.
- Continue to evaluate ASDP products during wildfires, when ASDP often provides the only PM2.5 data for the fire area.
- Projected ending ARL: ARL 8 (September 2013).

* * *

Project: Inverse Modeling and Attainment Analysis for Improved Decision Support of PM2.5 Air Quality Regulations

Principal investigator: Daven Henze, University of Colorado at Boulder

Project year: 3 (final)

Year-end ARL: 4

Description:

Applying environmental data from multiple remote sensors, the project aims to inform updates to the National Emissions Inventory (NEI) for the PM2.5 precursors NH₃ and NO_x. Additional objectives:

- Assist the Regulatory Impact Assessment (RIA) by improving the specificity of cost-per microgram metrics in terms of spatial resolution and source attributes.
- Provide information regarding the impact of individual sources on multiple nonattainment monitors.

End users: EPA

Data sources, models, technology: MODIS radiances and AOD; TES NH₃; OMI and SCIAMACHY NO₂; GEOS-Chem

Major accomplishments in CY 2012:

- Provided guidance on how remote sensing observations provide constraints on emissions of short-lived species. Published paper in *Geophysical Research Letters*, 39: Turner et al., "The spatial extent of source influences on modeled column concentrations of short-lived species."

- Developed the adjoint model of the most commonly used algorithm for calculating aerosol-gas partitioning. Published paper in *Atmospheric Chemistry & Physics*, 12: Capps et al., "ANISORROPIA: the adjoint of the aerosol thermodynamic model ISORROPIA."
- Quantified the impacts on human health of aviation emissions using GEOS-Chem adjoint sensitivity analysis. Submitted paper to *Atmospheric Environment*: Koo et al., "Spatial sensitivities of human health risk to intercontinental and high-altitude pollution."
- Reduced uncertainty in U.S. ammonia emissions through the use of NASA TES remote sensing observations. Submitted paper to *Journal of Geophysical Research*: Zhu et al., "Constraining U.S. ammonia emissions using TES remote sensing observations and the GEOS-Chem adjoint model."

Plans or expectations for 2013:

- Evaluate CMAQ and GEO-Chem model estimates of the cost-per microgram of emissions due to premature mortality from exposure to black carbon aerosol in the United States.
- Explore how these costs are likely to change due to greenhouse gas-driven climate change.
- Use GEOS-Chem sensitivity analysis to analyze boundary conditions used by EPA regulatory modeling.
- Projected ending ARL: 8 (September 2013).

* * *

Project: Reducing Uncertainties in National Smoke Emissions Modeling as Applied in the BlueSky Framework: Dead and Live Fuel Moisture, Plume Rise, and Heat Release

Principal investigator: Dana Sullivan, Sonoma Technologies, Inc.

Project year: 4 (final)

Year-end ARL: 8

Description:

The project incorporates Earth science data into the BlueSky Smoke Modeling Framework and SmartFire fire information systems to reduce uncertainties associated with modeling air pollutant emissions and transport from biomass burning. BlueSky and SmartFire support decisions at the local, regional, and national scale, including (a) wildfire suppression prioritization, (b) prescribed burning go/no-go decisions, (c) airshed management, (d) public health notifications, and (e) creation of the U.S. National Emissions Inventories. Additional objectives:

- Address two key uncertainties: biomass consumption estimates derived from sparse fuel moisture data, and plume heights.
- Incorporate alternative means to calculate fire emissions: Fire Locating and Modeling of Burning Emissions (FLAMBÉ), and an application of FRP.

End users: EPA, USFS

Data sources, models, technology: TMPA-RT (to improve dead fuel moisture estimates); EastFire live fuel estimates derived from MODIS direct broadcast (to improve live fuel moisture estimates); MISR stereo lights (to improve estimate of plume heights); FLAMBÉ on the basis of fire detections and radiance measures from MODIS and *GOES*; FRP from MODIS

Major accomplishments in CY 2012:

- Completed and implemented the program module for live fuel moisture.
- Completed program modules for dead fuel moisture, fire radiative power, and plume heights.
- Published article in *Atmosphere*, 3: Raffuse et al., “An evaluation of modeled plume injection height with satellite-derived observed plume height.”
- Presented project results to date at the AGU Fall Meeting.

Plans or expectations for 2013:

- Complete testing and release of program module implementations.
- Complete benchmarking activities and socioeconomic benefits study.
- Prepare one or two articles for submission to peer-reviewed journals on technical improvements and/or socioeconomic benefits.
- Present project results at the AGU Fall Meeting and one to three other conferences.
- Projected ending ARL: 9 (September 2013).

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Project: Incorporating Space-borne Measurements to Improve Air Quality Decision Support Systems

Principal investigator: Arastoo Biazar, University of Alabama, Huntsville

Project year: 3 (final)

Year-end ARL: 4

Description:

Applying Earth observations and models, the project is improving the performance of the MM5/CMAQ and WRF/CMAQ (air quality management decision support tools) used in the State Implementation Plan (SIP) process for development and evaluation of emission controls under the provisions of the Clean Air Act. Additional objectives:

- Improve model location and timing of clouds in the meteorological model (MM5 or WRF).
- Improve chemical transboundary and initial conditions in the air quality model (CMAQ).
- Use a new NASA Lightning NO_x-production Model (LNOM) that accounts for lightning NO production in convective clouds in CMAQ.

End users: EPA, Texas Commission on Environmental Quality (TCEQ)

Data sources, models, technology: MODIS aerosol products, OMI ozone retrievals, MM5, WRF, CMAQ, LNOm

Major accomplishments in CY 2012:

- Integrated the assimilation technique for cloud correction into the WRF modeling system; tested, evaluated, and demonstrated improvement in cloud simulation.
- Started the process of transferring the new decision support tools to our partner in the user community (TCEQ) to be used in decision-making process.
- Revised the approach for LNOm LNOx calculations.
- Distributed the LNOm data to the user community (http://lightning.nsstc.nasa.gov/data/index.html#LNOm_DATA).
- Documented the technique and its first application within WRF/CMAQ.
- Incorporated OMI ozone retrievals and MODIS aerosol products in MM5/CMAQ air quality modeling system.
- Demonstrated the impact of utilizing OMI ozone and MODIS AOD in air quality simulations.
- Started to utilize LiDAR measurements to complement/refine the OMI retrievals.
- Presented project results at AGU Fall Meeting and AMS Annual Meeting.
- Published article in *Atmospheric Environment*, 54: Ngan et al., "Performance assessment of retrospective meteorological inputs for use in air quality modeling during TexAQS 2006."

Plans or expectations for 2013:

- Hold a user workshop to train individuals from the state and local regulatory community and the private environmental consulting community.
- Finish benchmarking activities by working with EPA and TCEQ for independent evaluation of tools and techniques for cloud correction.
- Finish LNOm/CMAQ evaluation.
- Upgrade the current Web-based data delivery system to accommodate tools and documentations from this project.
- Distribute models, tools, and documentation from this project to the broader user community through CMAS.
- Projected ending ARL: 7 (September 2013).

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Air Quality Applied Sciences Team (AQAST) Project Highlights

Project: Improving Air Quality Analysis through a Closer Integration of Observations and Models

Principal investigator: Gregory Carmichael, University of Iowa

Project year: 2

Description:

Integrating Earth observations and models, this project seeks to improve the capability to model fine particle concentrations during wintertime episodes in the Midwest, Northeast, Mountain West, and California's Central Valley. Additional objectives:

- Establish an operational urban/regional air pollution forecasting system for decision support by state air quality bureaus and public- and private-sector emissions sources, and archive regional air quality model results for use in planning by local, state, and regional air quality managers.
- Quantify the value of assimilating remote sensing of combined atmospheric composition, land cover, and meteorology on regional air quality model performance.

End users: EPA, state air quality agencies

Data sources, models, technology: MODIS, *GOES*, OMI, WRF-Chem, WRF-AERMOD, CMAQ, SNODAS

Major accomplishments in CY 2012:

- Published manuscript in *Atmospheric Chemistry and Physics* (12) on wintertime fine particles that improved the understanding of regional wintertime air quality events in the Midwest: Stanier et al., "Overview of the LADCO winter nitrate study: Hourly ammonia, nitric acid and PM_{2.5} composition at an urban and rural site pair during PM_{2.5} episodes in the U.S. Great Lakes region."
- Published manuscript in *Proceedings of the National Academy of Sciences* (109/30) on a new technique to assimilate satellite data to improve aerosol predictions under cloudy conditions using cloud droplet number to constrain aerosol number concentration: Saide et al., "Improving aerosol distributions below clouds by assimilating satellite-retrieved cloud droplet number."
- Responded to urban air quality event (Iowa City landfill's tire liner caught fire and burned for 14 days in May and June): implemented a WRF-AERMOD forecast for PM_{2.5}, CO, SO₂, and VOCs, constrained by MODIS cloud products, which was operational within 60 hours. Used that forecast to direct an intensive field campaign with two mobile platforms and three monitoring stations, which sampled time-resolved PM_{2.5}, black carbon, aerosol size and number distributions, CO, CO₂, SO₂, and 40+ organic carbon molecular markers. Inverted these observations to constrain emissions rates. Provided daily model forecasts of eight-hour average PM_{2.5} concentrations to Johnson County Public Health in support of public messaging.
- Above collaboration with University of Iowa faculty, Johnson County Public Health, and the State of Iowa Hygienic Laboratory led to an invited workshop at the upcoming April 2013 Iowa Governor's Conference on Public Health.

Plans or expectations for 2013:

- Publications on wintertime PM_{2.5} in the Midwest: first modeled process analysis of nitrate chemistry and thermodynamics; first model evaluation for wintertime episode

performance; role of assimilated snow properties on photochemical model performance; impacts of emitted species, sectors, regions, and 2015 proxy scenarios.

- Publications and guidelines on modeling and remote sensing applications for air quality, public health, and emergency management decision support during high impact urban air quality events (e.g., tire fires), including best practices for decision support tools; tire fire trace gas and aerosol emissions profile; observed effects on air quality of the 2012 Iowa City landfill fire.
- Publication on source contributions to nitrogen deposition to U.S. National Parks in the present and future (tiger team activity).
- Continue development and testing of assimilation in cloudy and mixed-cloud conditions to improve air quality and weather forecasts.
- Continue to investigate impacts of regional and distant sources on surface ozone in the western United States (tiger team activity).
- Operationalize forecast test bed system.

* * *

Project: Opportunities to Inform Attainment Planning

Principal investigator: Daniel Cohan, Rice University

Project year: 2

Description:

Utilizing satellite observations together with regional photochemical models such as CMAQ or CAMx, this project aims to better understand the emission sources of nitrogen oxides and other species, through inverse modeling or other methods. Additional objectives:

- Improve understanding of the magnitudes and inter-annual variability of biogenic emissions of hydrocarbons and nitrogen oxides.
- Interact with scientists and officials from state and federal air quality agencies to facilitate the use of the best available science, modeling, and observations to inform the development of cost-effective air quality strategies.

End users: EPA, state air quality agencies

Data sources, models, technology: MODIS, OMI, CMAQ, CAMx, Kalman filter, WRF, WRF-Chem

Major accomplishments in CY 2012:

- Conducted Kalman filter inverse modeling of NO_x emissions in Texas and surrounding states, based on NASA Standard Product retrievals of OMI NO₂ measurements and the CAMx photochemical model. Modeled the impacts on NO_x and ozone concentrations and sensitivities to emissions.
- Applied the MEGAN biogenic emissions model to quantify the variability in biogenic VOC emissions resulting from variability in leaf area index from two data sets.

- Presented an overview of ACAST at the annual meeting of the Central States Air Resource Agencies. The ensuing discussions led to creation of a website of the scholarly expertise of ACAST scientists, to facilitate state agencies and others in building partnerships with our team.
- Presented results at two meetings of the ACAST team.
- Presented “Kalman filter inversion of regional NO_x emissions based on OMI NO₂ observations,” at AGU Fall Meeting (December).

Plans or expectations for 2013:

- Implement Hudman soil NO_x scheme in the CMAQ model together with dynamic data for fertilizer application, and test its impact on NO₂ concentrations relative to satellite observations and on O₃ concentrations and sensitivities.
- Write manuscript analyzing how concentrations of isoprene and other VOCs vary with meteorological conditions, drought, and leaf area index.
- Write manuscript using temporal patterns of NO₂ from the BEHR OMI retrieval to diagnose the sources of NO_x emissions in each location.
- Participate in and present results at two meetings of ACAST.
- Continue to build partnerships with EPA and air quality agencies in Texas, Georgia, California, and elsewhere to conduct modeling and research relevant to O₃ and PM SIP development.

* * *

Project: Air Pollution over the Eastern United States: Integration of *Aura*/OMI NO₂ and SO₂, Aircraft, and Ground-based Observations with Numerical Models

Principal investigator: Russell Dickerson, University of Maryland

Project year: 2

Description:

Employing NASA satellite and aircraft observations, the project aims to generate policy relevant science for state and local air quality managers. Additional objectives:

- Investigate chemistry-meteorology interactions to understand the budgets, transport, and transformations of short-lived climate forcers and other air pollutants.

End users: state and local air quality managers

Data sources, models, technology: DISCOVER-AQ, OMI

Major accomplishments in CY 2012:

- Investigated the use of satellite measurements in the trend of CO over the eastern United States. Submitted paper to *Atmospheric Chemistry and Physics Discussions*: He et al., “Trends in emissions and concentrations of air pollutants in the lower troposphere in the Baltimore/Washington airshed from 1997 to 2011.”

- Developed a method based on *in situ* and remotely sensed data as well as numerical models to balance the S budgets. Published manuscript in *Journal of Geophysical Research*: Hao et al., “SO₂ over central China: Measurements, numerical simulations, and the tropospheric sulfur budget.”
- Investigated the role of aerosols in radiative balance. Published manuscript in *Journal of Geophysical Research*: Giles et al., “An analysis of AERONET aerosol absorption properties and classifications representative of aerosol source regions.”
- Used DISCOVER-AQ data to help shape policy for the Maryland Department of the Environment. Published manuscript in *Journal of Atmospheric Chemistry*: Stauffer et al., “Bay breeze influence on surface ozone at Edgewood, Maryland, during July 2011.”
- Presented ACAST results from DISCOVER-AQ and other studies at AGU Fall Meeting, four MDE (Maryland Department of the Environment) meetings, Ozone Transport Commission (OTC), and Mid-Atlantic Regional Air Management Association (MARAMA).
- Advised MDE, OTC, and MARAMA on air quality science.

Plans or expectations for 2013:

- Use the OMI and DISCOVER-AQ observations to evaluate the chemistry, meteorology, and emissions in WRF/CMAQ and improve our understanding of ozone formation.
- Submit manuscript to *Atmospheric Environment*: Goldberg et al., “Surface ozone concentrations over the Chesapeake Bay during DISCOVER-AQ.”
- Submit manuscript to *Atmospheric Environment*: Hao He et al., “An elevated reservoir in a six-day pollution event over the mid-Atlantic states: a case study from airborne measurements and numerical simulations.”
- Complete manuscript: Loughner et al., “Impact of bay breeze circulations on surface air quality and boundary layer export.”
- Demonstrate the change in SO₂ resulting from Maryland’s Healthy Air Act using *in situ* and OMI observations.
- Host June ACAST meeting in College Park, Maryland.

* * *

Project: Application of OMI Observations

Principal investigator: Bryan Duncan, NASA Goddard Space Flight Center

Project year: 2

Description:

This project is expanding the application of OMI observations:

- Prepare a review article (i.e., air quality user’s guide) that delivers information in plain language on how best to use satellite data for air quality applications.
- Augment (and update as needed) the ARSET website with helpful information, including answers to frequently asked questions and common mistakes to avoid.

- Lead a modeling study of the benefit of emission controls since 2002 on pollution in the eastern United States during July 2011, the hottest month recorded in the Mid-Atlantic.
- Use the latest version of the *Aura*/OMI NO₂ data product to assess the correspondence of known emission changes (associated with the implementation of control devices) and the data. This work will help air quality end users to understand this association, which is known to vary regionally and seasonally.

End users: air quality managers

Data sources, models, technology: OMI, CMAQ

Major accomplishments in CY 2012:

- Outlined the air quality user's guide, coordinated contributions with AQUEST and ARSET co-authors, and began writing.
- Completed most of the analysis for a manuscript on the response of OMI NO₂ (high resolution latest version) to reductions in power plant emissions during the *Aura* record. Began writing a journal article.
- Worked with MDE staff on a project to conduct a CMAQ modeling study of the benefit of emission controls since 2002 on air quality in the eastern United States. Completed an initial analysis with both OMI and surface data. The MDE staff noted that the majority of the public believes that air quality is getting worse, so they feel that this work will help to change this negative perception.
- Completed surveys of NASA scientists, air quality managers, and data end users to identify barriers for the air quality community to use satellite data for their applications. Prepared a summary document on recommended activities for AQUEST to address these barriers.

Plans or expectations for 2013:

- Complete the user's guide review article and augmentation of ARSET website.
- Complete the article on the correspondence of OMI NO₂ data to known emission reductions from U.S. power plants. Coordinate with OMI algorithm developers to address issues with the OMI product, particularly in mountainous and desert terrain.
- Complete model simulations and submit a journal article on the benefit of emission controls in the eastern United States since 2002. Work with MDE staff to create a press release to educate the public on improving air quality as determined by satellite and surface data and modeling work.

* * *

Project: Integrating Satellite Observations of Tropospheric Pollutants

Principal investigator: David Edwards, National Center for Atmospheric Research

Project year: 2

Description:

This project aims to provide chemical boundary conditions to the eight-hour Ozone SIP Photochemical Modeling for the North Front Range Non-Attainment Area. Additional objectives:

- Analyze satellite data in support of exceedance demonstration for high surface events due to stratospheric intrusions.
- Increase understanding of the impact of western wildfires on air quality and quantifying health impacts.
- Constrain NO_x emissions using OMI NO₂ columns and WRF-Chem.

End users: air quality agencies

Data sources, models, technology: OMI, IASI, WRF-Chem, MOZART-4

Major accomplishments in CY 2012:

- Denver SIP modeling: included initial and boundary conditions from the MOZART-4 model. RAQC preparing the SIP final report.
- DISCOVER-AQ/FRAPPÉ: coordination with local and regional agencies, universities, and research centers to propose a Front Range field campaign. NASA is committed to bringing the fourth DISCOVER-AQ campaign to the Front-Range if NCAR can contribute the C-130 aircraft.
- Used IASI CO and O₃ retrievals for the well documented May 2010 stratospheric intrusion event over Colorado to demonstrate the potential of IASI data for SI demonstration.
- Contributed to D. Henze's tiger team for source contributions to seasonal vegetative exposure to ozone: performed WRF-Chem simulations with tagged ozone.
- Contributed to A. Thompson's tiger team for statistical air quality forecast support during DISCOVER-AQ: supported ensemble modeling by providing WRF-Chem simulations for downscaling and by creating emissions inputs.
- Collaborated with Colorado Department of Public Health and Environment on using WRF-Chem, satellite and *in situ* data to look into air quality and health impacts of fires in Colorado in June 2012 and support exceedance demonstrations. Conducted first WRF-Chem simulations and evaluations.
- Presented at AQUEST meetings and AGU Fall Meeting.
- Published manuscript in *Geophysical Research Letters*: Ghude et al., "Satellite constraints of Nitrogen Oxide (NO_x) emissions from India based on OMI observations and WRF-Chem simulations."

Plans or expectations for 2013:

- Tiger team activity on air quality and health impacts of June 2012 Colorado wildfires.
- Continue contributions to SI working group and to D. Henze's tiger team.
- Use regional climate simulations conducted as part of an NSF grant to specifically analyze the results for Colorado and convey to the air quality agencies. Discussions during the RAQC Ozone Modeling Forum (August 2012) showed the interest of Colorado in having future air quality predictions, but also the limited capabilities.

* * *

Project: Estimating Background Ozone, and its Specific Components, over the Western United States to Support NAAQS Setting, Implementation, and Attainment Planning

Principal investigator: Arlene Fiore, Columbia University

Project year: 2

Description:

Using the GFDL AM3/CM3 chemistry-climate model, satellite retrievals, and *in situ* measurements, this project seeks to apply an integrated analysis approach to quantify various components (Asian pollution, stratospheric, wildfire) of background ozone over the United States to inform the U.S. NAAQS-setting and implementation processes. Additional objectives:

- Explore the potential for developing space-based indicators of daily to inter-annual variability in the individual components of U.S. background ozone, with a focus on the western United States, where background levels are typically highest.
- Investigate how the processes controlling the relative importance of regionally produced versus transported pollution may be altered by a warming climate in combination with projected changes in pollutant precursor emissions.

End users: air quality managers

Data sources, models, technology: AIRS, OMI, GFDL AM3/CM, GEOS-Chem

Major accomplishments in CY 2012:

- Completed process-oriented analyses of the GFDL AM3 model nudged to re-analysis winds for direct comparison with CalNex measurements and satellite retrievals for spring of 2010 over the western United States to diagnose Asian (including from space) and stratospheric contributions to surface ozone, including pollution episodes.
- Published manuscript in *Journal of Geophysical Research*, 117: Lin et al., "Transport of Asian ozone pollution into surface air over the western United States in spring."
- Published manuscript in *Journal of Geophysical Research*, 117: Lin et al., "Springtime high surface ozone events over the western United States: Quantifying the role of stratospheric intrusions."
- Led tiger team comparison of North American background estimates from AM3 and GEOS-Chem and evaluation with surface and satellite measurements. Contributed AM3 model simulations and analysis to tiger teams led by D. Henze (W126 exposure and source attribution) and by R. B. Pierce (air quality forecasting).
- Provided figures for EPA Integrated Science Assessment (Asian, stratospheric influence, comparison of AM3 and GEOS-Chem models for 2006 ozone season).
- Presented ACAST work at NASA, air quality meetings, on calls with air quality managers; ACAST overview at the WESTAR air quality meeting.

- Published review: Fiore et al., “Global air quality and climate,” *Chemical Society Reviews*, 41.

Plans or expectations for 2013:

- Complete review of background ozone and GEOS-Chem and AM3 comparison.
- Continue scoping out space-based indicators of stratospheric influence on daily and inter-annual time scales over the western United States.
- Identify drivers of year-to-year and long-term variability in the specific components of U.S. background ozone in surface air.
- Examine role of horizontal resolution in estimates of surface stratospheric influence.
- Explore climate-driven changes in future U.S. ozone air quality in the context of changing regional, global (including methane) precursor emissions.

* * *

Project: Studies of the Relationship Between Satellite-derived Trace Gas Measurements and Surface Observations

Principal investigator: Jack Fishman, Saint Louis University

Project year: 2

Description:

The project is using oversampling to create high resolution maps of SO₂ around point sources and to estimate SO₂ lifetimes. Additional objectives:

- Work with local regulatory agencies and utility companies to provide a mechanism by which satellite measurements can be used to better understand local air quality issues.
- Lead AQAST education/public outreach.

End users: air quality managers

Data sources, models, technology: OMI, CAMx

Major accomplishments in CY 2012:

- Continued oversampling of SO₂, with estimation of lifetime by season for different point sources.
- Compared trends in OMI SO₂ and NO₂ data with surface concentration time series to evaluate the difference between air quality evaluations based on satellite data vs. those based on ground monitoring equipment.
- Contacted the Air Quality Advisory Council of the East-West Council of Governments and with the air quality supervisor of UE Ameren, the local power utility company, to learn about air quality issues in the greater St. Louis region.
- Coordinated with Saint Louis Science Center and Missouri Botanical Garden to design and implement first “Ozone-Induced Foliar Injury Garden” in St. Louis using template provided by Ladd et al. (2011; NASA NP-2011-03-355-LaRC).

- Planted St. Louis Ozone Garden May 5 near entrance to Saint Louis Science Center's McDonnell Planetarium in Forest Park.
- Made available real-time O₃ measurements from the St. Louis Ozone Garden through the Global O₃ Project (*GO3Project.com*).
- Published summary of 2012 Ozone Garden accomplishments on ACAST site.

Plans or expectations for 2013:

- Publish SO₂ lifetime project.
- Develop analysis of OMI and surface monitoring trends.
- Develop inverse modeling for forest fire emission factors.
- Obtain formal membership into the Air Quality Advisory Committee of the East-West Council of Governments and formulate a plan for implementation of remotely sensed information into the committee's strategy for better understanding and improving air quality.
- Submit and publish manuscript about St. Louis Ozone Garden in *Bulletin of American Meteorological Society*.
- Develop Ozone Garden Network in St. Louis metropolitan area by planting two additional gardens (one upwind and one downwind of the metropolitan area).
- Collaborate with other ACAST principal investigators to create national network of ozone gardens by establishing one or two gardens outside the St. Louis metropolitan area.

* * *

Project: Using Remote Sensing and Adjoint Modeling for Integration of Climate Impacts into Design of Ozone and Aerosol Control Strategies

Principal investigator: Daven Henze, University of Colorado at Boulder

Project year: 2

Description:

Using GEOS-Chem adjoint model sensitivities, this project aims to quantify the contribution of emissions to ozone and PM health impacts. Additional objectives:

- Determine aerosol and tropospheric ozone radiative forcing efficiencies using adjoint model sensitivities and remote sensing constraints (MODIS, TES).
- Incorporate radiative forcing and health impact efficiencies into national and global-scale decision support tools to examine co-benefits of air quality and climate mitigation strategies.

End users: EPA, USFS, National Park Service

Data sources, models, technology: MODIS, TES, GEOS-Chem

Major accomplishments in CY 2012:

- Determined the contribution to radiative forcing efficiency from regionally specific emissions of aerosol and aerosol precursors, and applied these to assess aerosol RF across the IPCC RCP scenarios. Published manuscript in *Environmental Science & Technology*, 46: Henze et al., “Spatially refined aerosol direct radiative forcing efficiencies.”
- Quantified the radiative forcing of NO_x, CO, and NMVOC emissions as measured by TES using GEOS-Chem adjoint model sensitivities. Published manuscript in *Geophysical Research Letters*, 39: Bowman et al., “Attribution of direct ozone radiative forcing to spatially-resolved emissions.”
- Used the adjoint of GEOS-Chem to investigate the sources contributing to nitrogen deposition in worldwide biodiversity hotspots including two U.S. national parks. Submitted manuscript to *Environmental Science & Technology*: Paulot et al., “Sources and processes contributing to nitrogen deposition in biodiversity hotspots worldwide.”
- Examined impacts of internalizing the environmental cost of PM and greenhouse gas emissions into their price within the EPA’s MARKAL energy system model.
- Led an ACAST tiger team investigating impacts of background ozone on proposed secondary standards for ozone; presented results at ACAST and AGU meetings.

Plans or expectations for 2013:

- Lead new ACAST tiger team that will provide information to the EPA, Forest Service, and National Park Service regarding sources of nitrogen deposition.
- Provide radiative forcing and health impacts efficiencies to the UNEP Climate and Clean Air Coalition.
- Expand analysis of tropospheric ozone radiative forcing to include a complete year of TES data, and account for long-term feedbacks via methane.
- Continue to lead ACAST tiger team focused on background ozone impacts on vegetative exposure in the United States.

* * *

Project: Evaluating Emissions, Air Quality, and CMAQ Performance with Satellite Data

Principal investigator: Tracey Holloway, University of Wisconsin at Madison

Project year: 2

Description:

Incorporating satellite data, the project intends to assess spatial and temporal variability in anthropogenic emissions, and sector-specific impacts on air quality. Additional objectives:

- Evaluate climate-chemistry relationships, especially to validate the EPA CMAQ model.
- Help lead ACAST activities and interactions with the media, the public, and NASA.

End users: EPA and state air quality managers

Data sources, models, technology: CMAQ, OMI, MODIS

Major accomplishments in CY 2012:

- Developed new approach for high-resolution future climate scenarios, targeting air quality analysis. Submitted manuscript to *Journal of Geophysical Research*: Harkey and Holloway, "Constrained dynamical downscaling for assessment of climate impacts."
- Developed a bottom-up freight emissions inventory based on commodity flow data from the Federal Highway Administration. Published manuscript in *Transportation Research Part D*, 17D (1): Johnson et al., "Impacts of biodiesel blending on freight emissions in the Midwestern United States."
- Evaluated the performance of the CMAQ model for atmospheric mercury chemistry. Published manuscript in *Atmospheric Chemistry and Physics*, 12: Holloway et al., "An assessment of atmospheric mercury in the Community Multiscale Air Quality (CMAQ) model at an urban site and a rural site in the Great Lakes Region of North America."
- Developed an open-source program to make satellite-derived air quality data more usable for the air quality management community, the Wisconsin Horizontal Interpolation Program for Satellites (WHIPS). Functional for OMI NO₂, MODIS AOD, and MOPITT CO.
- Presented WHIPS as a module in a training program led by the NASA ARSET program held at the University of Wisconsin, Madison (March) for regional air quality managers.
- Evaluated the performance of CMAQ for NO₂ based on ground-based and satellite (OMI) data, based on ambient concentrations and climate sensitivities; presented results at AGU Fall Meeting (talk by T. Holloway; poster by M. Harkey).
- Launched a media and public outreach initiative for ACAST, via Twitter and a new website (in final stages) to build broader awareness of ACAST activities.

Plans or expectations for 2013:

- Expand ACAST outreach activities, including release of new site: media.aqast.org.
- Complete analysis of NO₂ with CMAQ, ground-based, and satellite, including climate sensitivities as reflected in model versus observed data.
- Quantify U.S. truck and rail freight signatures apparent in OMI NO₂.
- Assess sector contributions to ground-level ozone under differing air quality conditions.

* * *

Project: Quantitative Integration of Satellite Observations and Air Quality Models driven by Detailed Analysis of Observability

Principal investigator: Edward Hyer, Naval Research Laboratory

Project year: 2

Description:

Integrating satellite observations and air quality models, this project aims to develop and disseminate Level 3 satellite aerosol data products custom-made for air quality modeling

applications, including comprehensive quality assurance as well as uncertainty estimates for each observation.

- Improve descriptions of wildfire smoke release through improved exploitation of satellite observations of fire and models of fire detection efficiency and quantitative models of fire-weather interaction.
- Improve models of fire-weather interaction that can be used to integrate weather data with satellite observations of fires for more accurate analysis of fire activity, as well as for short-term prediction of fire activity to support applications needing forecasts of air quality.

End users: NOAA, EPA, and state air quality managers

Data sources, models, technology: MODIS

Major accomplishments in CY 2012:

- Delivered a new value-added Level 3 AOD product to NASA LANCE; assisted with implementation of the product on NASA's Near Real Time data production system. The product, which is used operationally by Navy for aerosol forecasting, is now available to the public within nine hours after overpass from LANCE.
- Prepared a novel method for short-term forecasting of regional fire activity using NASA satellite data and numerical weather prediction model output, as described in the pending article in *Atmospheric Environment*: Peterson et al., "A short-term predictor of satellite-observed fire activity in the North American boreal forest: toward improving the prediction of smoke emissions."
- Published a novel method for retrieval of sub-pixel fire properties from MODIS radiance data, in *Remote Sensing of Environment*, 129: Wang et al., "A sub-pixel-based calculation of fire radiative power from MODIS observations: 1: Algorithm development and initial assessment."
- Presented results from ACAST research at community forums, including ACAST meetings at California Air Resources Board, as well as AMS, AGU, and the AWMA specialty conference on visibility and air quality.
- Provided data and consultation on fire and AOD to ACAST and non-ACAST researchers, including NOAA Air Resources Lab, the Carmichael group at the University of Iowa, and a NASA group working with the California Air Resources Board.

Plans or expectations for 2013:

- Develop and deliver a value-added Level 3 AOD product based on MODIS Collection 6 for production at NASA LANCE.
- Revise and improve fire activity forecasting methods using improved fire time series.
- Evaluate fire activity forecasting approach in atmospheric model simulation of real fire events.
- Develop an AOD product for air quality applications from VIIRS, modifying the filtering, correction, and uncertainty estimation procedures developed for the MODIS product.
- Continue to participate in ACAST activities, including meetings, collaborations, and ACAST "satellite data user guides."

- Conduct a study of interstate and intrastate pollution transport as it affects Midwestern states with emphasis on the effects of large western fires. This is an ACAST tiger team project.

* * *

Project: U.S. Air Quality Issues at the National/International Scale and Coupling with Climate

Principal investigator: Daniel Jacob, Harvard University

Project year: 2

Description:

Using the GEOS-Chem global atmospheric composition model with nested capability over North America, together with information from satellite instruments, this project aims to address emerging U.S. air quality issues at the national/international scale. Additional objectives:

- Investigate chemistry-climate interactions relevant to U.S. air quality management using the NASA/GISS general circulation model together with long-term correlations of air quality data with meteorological variables.
- Lead ACAST activities and interactions with the air quality management community.

End users: NPS, EPA, state air quality managers

Data sources, models, technology: OMI, TES, GEOS-Chem, NASA/GISS general circulation model

Major accomplishments in CY 2012:

- Developed a new method for estimating the effect of climate change on PM_{2.5} air quality in the United States through the correlation of regional PM_{2.5} with synoptic meteorological modes. Published manuscript in *Atmospheric Chemistry and Physics*, 12: Tai et al., "Meteorological modes of variability for fine particulate matter (PM_{2.5}) air quality the United States: implications for PM_{2.5} sensitivity to climate change."
- Reduced the uncertainty in estimates of the effect of climate change on PM_{2.5} air quality in the United States through multi-model analysis of meteorological modes. Published manuscript in *Atmospheric Chemistry and Physics*, 12: Tai et al., "Impact of 2000-2050 climate change on fine particulate matter (PM_{2.5}) air quality inferred from a multi-model analysis of meteorological modes."
- Used the adjoint of GEOS-Chem to investigate the sources contributing to nitrogen deposition in worldwide biodiversity hot spots including two U.S. national parks. Submitted manuscript to *Environmental Science & Technology*: Paulot et al., "Sources and processes contributing to nitrogen deposition in biodiversity hotspots worldwide."

- Used GEOS-Chem to estimate nitrogen deposition in U.S. national parks and diagnose critical load exceedances including future projections; presented results at AGU Fall Meeting.
- Presented ACAST overviews at several NASA and air quality meetings.
- Organized two ACAST meetings (June in Madison; November in Sacramento); rebuilt the ACAST website; conducted the FY 2012 tiger team proposals review; managed other ACAST activities.

Plans or expectations for 2013:

- Use the GEOS-Chem adjoint for inverse analysis of U.S. ammonia emissions as constrained by ammonium wet deposition fluxes, and use a new bottom-up inventory to interpret the results.
- Improve the GEOS-Chem simulation of background surface ozone in the United States and evaluate a new TES tropospheric ozone product for quantifying this background.
- Revise previous estimates of the effect of climate change on surface ozone air quality by accounting for the CO₂ dependence of isoprene emission.
- Continue to lead ACAST activities.

* * *

Project: Chemical Reanalysis to Provide Estimates of the True Chemical State of the Atmosphere

Principal investigator: Pius Lee, Air Resources Lab, NOAA

Project year: 2

Description:

This project intends to serve the atmospheric chemistry and global chemical weather community with reanalysis products. Additional objectives:

- Ingest large observation data sets to constrain CMAQ 5.0, to produce downloadable reanalysis fields with reasonable temporal and spatial resolution—helpful to both measurement validation/calibration scientists as well as atmospheric chemistry modelers.
- Utilize the NCEP meso-gamma real-time meteorological forecast to drive CMAQ at fine horizontal scale to give on-demand air quality forecasting. This service has been proven invaluable for the previous two DISCOVER-AQ campaigns, and will be improved and be applied to other campaigns in the United States.

End users: atmospheric chemistry, global chemical weather community

Data sources, models, technology: MODIS, CMAQ 5.0, NAQFC

Major accomplishments in CY 2012:

- Quantified the forecast information values and errors of the National Air Quality Forecasting Capacity (NAQFC) products that were used for real-time flight planning support of the DISCOVER-AQ field campaign. Submitted manuscript to *Journal of Atmospheric Chemistry*: Garner et al., “Evaluation of NAQFC model performance in forecasting surface ozone during the 2011 DISCOVER-AQ campaign.” Submitted manuscript to *Geoscientific Model Development Discussions*: Chai et al., “Evaluation of the U.S. NAQFC experimental real-time predictions in 2010 using AQS O3 and NO2 measurements.”
- Reduced PM bias in NAQFC by accounting for extra domain wildfires detected by geostationary and polar-orbiting satellites. Submitted manuscript to *Air Pollution Modeling and its Applications*, Vol. XIII, Steyn and Builtjes, eds.: Lee et al., “Ingestion of intermittent wildfire sources inside and outside the forecasting domain.”
- Presented a prototype rapid response fine resolution air quality forecasting capacity for limited-area domains: Lee et al., “Fine resolution air quality forecasting capacity for limited-area domains—tested as proxy *GOES-R* retrievals over eastern Texas,” Fourth International Workshop on Air Quality Forecasting and Research, WMO headquarters, Geneva (December).

Plans or expectations for 2013:

- Begin to generate a prototype data product through chemical reanalysis of assimilating several of the key observation data sets, such as MODIS AOD and AIRNow PM2.5 concentrations.
- Continue to provide real-time fine resolution air quality forecasting support for flight plans for field campaigns—notably the DISCOVER-AQ campaign, Texas, in September.
- Improve marine isoprene emission modeling through the use of *in situ* shipboard and airborne data from the aforementioned Texas campaign.

* * *

Project: Improving Satellite Aerosol Remote Sensing Data for Air Pollution Health Research

Principal investigator: Yang Liu, Emory University

Project year: 2

Description:

Using custom retrieved satellite aerosol data and spatial statistical models, this project seeks to address emerging PM2.5 air pollution issues in the United States. Additional objectives:

- Study the linkage between spatially resolved PM2.5 concentrations and various adverse health outcomes.
- Support the air quality management needs of federal, state, and local government agencies.

End users: air quality managers (federal, state, local); California Air Resources Board; Bay Area Air Quality Management District

Data sources, models, technology: GEOS-Chem, MISR, DISCOVER-AQ, NLCD, NEI, NLDAS, *Landsat*, MODIS

Major accomplishments in CY 2012:

- Developed a Bayesian method for high-resolution aerosol retrieval based on MISR observed atmospheric radiances. Presented results at AGU Fall Meeting: Moon et al., "Evaluation of a MISR-based high-resolution aerosol retrieval method using DISCOVER-AQ mission data."
- Contributed to an AQUEST team-wide review paper (submitted to *Atmospheric Environment*): Streets et al., "Emissions estimation from satellite retrievals: A review of current capability."
- Contributed to an AQUEST team-wide discussion paper (to be submitted to *Atmospheric Environment*): Duncan et al., "Satellite Data for Air Quality Monitoring: Examples of Applications, Answers to FAQs, and Common Mistakes to Avoid."
- Used GEOS-Chem and MISR aerosol microphysical properties to predict particle sulfate levels in the past decade in the United States. Presented results at AGU Fall Meeting (December): Liu et al., "Satellite-observed trend in sulfate concentrations in the continental U.S."
- Contributed to the FY 2012 tiger team proposals review.

Plans or expectations for 2013:

- Continue the collaboration with Georgia Environmental Protection Division on improving fire emission inventory using *Landsat* data.
- Establish connection with Colorado Department of Public Health and Environment in preparation for the tiger team Year 2 project. The goal is to study the population health impacts due to acute exposure to wildfire smoke plumes.
- Collaborate with California Air Resources Board to apply high-resolution MISR aerosol retrievals to Southern California.
- Collaborate with Bay Area Air Quality Management District on the application of NASA satellite data (aerosol and cloud) to address local air quality management needs.

* * *

Project: Improving the Physical Atmosphere in Air Quality Modeling through Satellite Data

Principal investigator: Richard McNider, University of Alabama, Huntsville

Project year: 2

Description:

This project aims to increase understanding of the physical atmosphere and its relationship to air quality using satellite data. Additional objectives:

- Incorporate satellite data to improve representation of the physical atmosphere in air quality models used for SIPs and air quality forecasting.
- Involve physical atmosphere community in ACAST activities.

End users: air quality managers, California Air Resources Board, Bay Area Air Quality District

Data sources, models, technology: *GOES*, MODIS, CMAQ, CAMx, WRF

Major accomplishments in CY 2012:

- Formed Physical Atmosphere Advisory Team made up of recognized experts from academia and federal and state governments to review shortcomings of present understanding/representation of the physical atmosphere in air quality decision making.
- Held Physical Atmosphere Advisory Panel meeting in Atlanta (April). Developed priority list of physical atmosphere issues.
- Made presentation on Physical Atmosphere Advisory Panel meeting to full ACAST group in June in Madison, Wisconsin.
- Attended EPA/DOE/European workshop on integrated meteorology and chemistry models in Research Triangle Park (October).
- Made presentation on California physical atmosphere to California Air Resources Board/ACAST Meeting in Sacramento (November).
- Examined impact of lightning NO_x on free tropospheric chemistry. Submitted manuscript to *Atmospheric Environment*: Wang et al., "Estimating the influence of lightning on upper tropospheric ozone using NLDN lightning data and CMAQ model."
- Presented on the impact of physical atmosphere in air quality modeling, at AGU Fall Meeting (December): Pour Biazar et al., "The Impact of Physical Atmosphere on Air Quality and the Utility of Satellite Observations in Air Quality Models," Abstract GC21B-0956.
- Presented at 11th Annual CMAS Conference (October) on the use of satellite-derived photolysis in the CAMx modeling system as applied to Texas: Pour Biazar et al., "Assimilation of Satellite Observed Clouds in CAMx Modeling System."

Plans or expectations for 2013:

- Follow up on recommendations coming from Physical Atmosphere Advisory Panel meeting in Atlanta: use IR satellite data in Pleim-Xiu boundary layer assimilation scheme in WRF; examine improvements in air quality modeling in the stable boundary layer.
- Take a first look at using satellite data to evaluate and improve physical atmosphere in California. This will be done in association with California Air Resources Board and Bay Area Air Quality District.

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Project: NOAA/NESDIS Liaison for NASA Air Quality Science Team

Principal investigator: R. Bradley Pierce, NOAA NESDIS

Project year: 2

Description:

This project facilitates the utilization of NASA satellite measurements of atmospheric trace gases and aerosols in operational global air quality assimilation and forecasting systems.

Additional objectives:

- Contribute to assessments of the impact of NASA satellite trace gas and aerosol measurements on global air quality prediction through observing system experiments.
- Engage the NOAA Air Quality Research Program and state and local air quality agencies in the use of NASA satellite trace gas and aerosol measurements in air quality forecasting and assessment activities.

End users: NOAA, state and local air quality agencies

Data sources, models, technology: GFS, GEOS-Chem, IASI, DISCOVER-AQ

Major accomplishments in CY 2012:

- Developed and tested use of climatological 3-D tropospheric ozone production and loss (PL) distributions within the NOAA GFS to improve background ozone concentrations for NAQFC NAM-CMAQ air quality forecasts.
- Conducted Global Data Assimilation System (GDAS) cycling experiments using default GFS O3 PL (baseline) and with 3-D diurnally varying merged GFS/GEOS-Chem O3 PL.
- Results demonstrate that 3-D O3 PL results in slight reduction in UT/LS O3 high biases (~20%) and significant reduction in planetary boundary layer (PBL) bias with improved PBL variability compared to DISCOVER-AQ ozonesondes.
- Results show no statistically significant differences in Northern or Southern Hemisphere 500hPa 0-5 day height forecast skill but do show statistically significant increases in 50hPa tropical cold biases and reductions in 10hPa Southern Hemisphere warm biases.
- Conducted GDAS cycling experiments to assess the impact of assimilation of IASI ozone channel radiances within GDAS system using merged GFS/GEOS-Chem O3 PL.
- Results show no statistically significant differences in Northern or Southern Hemisphere 500hPa 0-5 day height forecast skill but do show statistically significant reductions in 10hPa 0-5 day ozone low biases and increases in 50hPa 0-5 day ozone high biases

Plans or expectations for 2013:

- Provide satellite based support to state and local air quality management for stratospheric intrusion (SI)-related exceptional event analysis through addition of trajectory-based SI forecasts initialized with real-time IASI and AIRS ozone retrievals within the Community Satellite Processing Package.

- Provide satellite based support to regional air quality management agencies for developing implementation plans for regional haze through delivery of MODIS based visibility retrievals to the EPA Remote Sensing Information Gateway.
- Continue to serve as NOAA *ex officio* member of ACAST.

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Project: Improving Operational Regional Air Quality Forecasting Performance through Emissions Correction Using NASA Satellite Retrievals and Surface Measurements

Principal investigator: Armistead Russell, Georgia Institute of Technology

Project year: 2

Description:

The project seeks to improve operational regional air quality forecasting performance through emissions correction using NASA satellite retrievals and surface measurements.

Additional objectives:

- Quantify the discrepancies between space and surface observations and the discrepancies between space observations and high-resolution modeled fields over regional scales; correct regional emission inventories via inverse modeling.
- Quantify the biases in the current regional emission inventories for multiple pollutants and estimate the uncertainty in corrected inventories.

End users: air quality forecasters, managers

Data sources, models, technology: MODIS AOD products, CMAQ, Daysmoke

Major accomplishments in CY 2012:

- Maintained the operational air quality forecasting system Hi-Res and disseminated the O₃ and PM_{2.5} forecasting products at <http://forecast.ce.gatech.edu> for local agencies and regional stakeholders. Various field campaigns use the Hi-Res products; the products will support the Southern Oxidant & Aerosol Study, May-June 2013.
- Used the MODIS AOD retrieval products of 3-km (pre-collection 6) and 10-km resolution (collection 51) to evaluate performances of several high-resolution (up to 1-km horizontal grid-spacing) episodic CMAQ simulations and the 2007 annual CMAQ 5.0.1 modeling for regulatory purposes over the Southeast. Described a portion of the results at AGU Fall Meeting (December): "Using satellite observations in performance evaluation for regulatory air quality modeling: Comparison with ground-level measurements." To be published.
- Investigated the uncertainties in biomass burning emissions and their impacts on simulating pollutant concentrations by using CMAQ and Daysmoke models. Utilized also estimates of biomass burning emissions derived from satellite retrieved information and by means of bottom-up methods, AOD retrievals, airborne measurements and

surface observations. Presented an evaluation of the uncertainties in biomass burning emissions presented at AGU Fall Meeting. To be published.

- Developed a hybrid method for PM_{2.5} source apportionment and for evaluating biases in emissions inventory.

Plans or expectations for 2013:

- Conduct a demonstration of improving air quality forecasting performance by correcting emissions with the operational Hi-Res forecasting system.
- Use CMAQ-DDM and the hybrid method to identify biases in the current NEI inventory, considering the spatial distribution of the biases in gridded emissions.
- Investigate discrepancies between space and surface observations, including satellite retrievals of AOD and NO₂, AERONET AOD observations, surface network measurements of NO₂ and PM species.
- Submit manuscript: Hu et al., "Fine particulate matter source apportionment using a hybrid chemical transport and receptor model approach."

* * *

Project: Emission Inventory Evaluation and Improvement Using Advanced Earth System Tools

Principal investigator: David Streets, Argonne National Laboratory

Project year: 2

Description:

The project is assessing the current capability of using satellite retrievals, particularly of NO₂ and SO₂, to estimate the emissions from point sources with reasonable accuracy, and to determine the conditions under which this capability is most reliable. Additional objectives:

- Test the ability to estimate point-source emissions from power plants in developing countries, particularly India and China, where large, new coal-fired power plants with high emissions have been constructed since the advent of satellite detection. In collaboration with other AQAST members, use regional chemical transport models to calculate column concentrations near these power plants and emission stack measurements as verification.
- Transfer the estimation techniques developed for large Asian sources to U.S. circumstances and test the capability. Extend the tests to area sources where possible.

End users: EPA

Data sources, models, technology: OMI, GOME, SCIAMACHY

Major accomplishments in CY 2012:

- Prepared review paper; submitted to *Atmospheric Environment*: Streets et al., "Emissions estimation from satellite retrievals: A review of current capability."
- Prepared a new, unit-based emission inventory for Indian thermal power plants for the period 1996-2010 and compared with satellite NO₂ observations from GOME, SCIAMACHY, OMI, and GOME-2. Found good agreement between NO₂ TVCDs and NO_x emissions for areas dominated by power plant emissions, as well as indications of a transition of the overall NO_x chemistry around 2005-2008. Published this work in *Environmental Science & Technology*, 46: Lu and Streets, "Increase in NO_x emission from Indian thermal power plants during 1996-2010: unit-based inventories and multi-satellite observations." The India work is continuing in collaboration with ACAST team member Greg Carmichael.
- Presented results at several NASA and EPA air quality meetings.

Plans or expectations for 2013:

- Publish the review paper and process the findings into a plan of action for testing U.S. point and area emissions.
- Compare satellite and STEM-modeled columns for India and extend the India NO₂ work to SO₂.
- Work with ACAST team member Bryan Duncan to compare NO₂ columns over U.S. power plants with EPA's CEMS stack measurements.
- Develop technique for estimating changes in U.S. development patterns from space.
- Apply Asian emissions techniques to the NASA SEAC4RS campaign in summer 2013.

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Project: Sustaining and Extending the Use of Earth Observations within EPA and the Larger Air Quality Community

Principal investigator: James Szykman, EPA Office of Research and Development

Project year: 2 (funding for FY 2012 ACAST activities provided by EPA)

Description:

This project seeks to improve air quality community user access to *CALIPSO* L2 data records. Additional objectives:

- Assess the value of high time resolution column and surface measurements for use at air quality monitoring stations.

End users: air quality community

Data sources, models, technology: *CALIPSO*, MODIS, WRF/CMAQ, OGC-WCS/WMS, Pandora spectrometer

Major accomplishments in CY12:

- Developed and implemented OGC-compliant Web Coverage Service (WCS) for *CALIPSO* L2 data products, with *CALIPSO* science team-recommend quality screening criteria, enhancing the use of distributed data access and processing across federal agencies via NASA *CALIPSO*-EPA Remote Sensing Information Gateway connection.
- Published manuscript in *AWMA EM*: Szykman et al., "Profile and remote sensing observation datasets (trace gases and aerosols) for regional-scale model evaluation under the Air Quality Model Evaluation International Initiative (AQMEII): North American and European perspectives."
- Delivered two years (2006 and 2010) of *CALIPSO* L2 extinction profiles and MODIS L2 AOD remapped onto U.S. and European model grids for use in AQMEII Phase II to JRC ENSEMBLE system.
- Submitted manuscript to *Journal of Atmospheric Chemistry*: Knepp et al., "Estimating surface NO₂ and SO₂ mixing ratios from fast-response total column observations and potential application to geostationary missions."

Plans or expectations for 2013:

- Develop and implement an OGC-compliant WCS to provide air quality relevant suborbital data from the NASA Airborne Data for Assessing Models system in multiple formats to enhance model evaluation activities within EPA and the Task Force on Hemispheric Transport of Air Pollution.
- Use DISCOVER-AQ observations to evaluate EPA Office of Research and Development high resolution runs of WRF/CMAQ for July 2011.

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Acronyms

AAAR: American Association for Aerosol Research
AAAS: American Association for the Advancement of Science
AERMOD: AMS/EPA Regulatory Model
AERONET: AErosol RObotic NETwork
AFHSC: Armed Forces Health Surveillance Center
AGU: American Geophysical Union
AIRS: Atmospheric Infrared Sounder
AM3: Atmospheric Component-3
AMS: American Meteorological Society
AMSR-E: Advanced Microwave Scanning Radiometer-EOS
ANISORROPIA: AdjoinT of ISORROPIA
AOD: aerosol optical depth
AQAST: Air Quality Applied Sciences Team
AQI: Air Quality Index
AQMEII: Air Quality Model Evaluation International Initiative
AQS: Air Quality System
ARL: Application Readiness Level
ARSET: Applied Remote Sensing Training
ASDP: AirNow Satellite Data Processor
ASTMH: American Society of Tropical Medicine and Hygiene
AVHRR: Advanced Very High Resolution Radiometer
AWMA: Air and Waste Management Association
BEHR: Berkeley High Resolution
Cal-ARB California Air Resources Board
CALIOP: Cloud Aerosol LiDAR Orthogonal Polarization
CALIPSO: Cloud-Aerosol LiDAR and Infrared Pathfinder Satellite Observations
CalNex: California Nexus
CAMx: Comprehensive Air Quality Model with Extensions
CCHHG: Climate Change and Human Health Working Group
CDC: Centers for Disease Control and Prevention
CEMS: continuous emission monitoring system
CenSARA: Central States Air Resources Agencies
CM3: Coupled Model-3
CMAQ: Community Multiscale Air Quality
CMAS: Community Modeling and Analysis System
CY: calendar year
DataFed: Federated Data System
DDM: direct decoupled method
DISCOVER-AQ: Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality
DOE: Department of Energy
DREAM: Dust REgional Atmospheric Model
EHVI: Extreme Heat Vulnerability Index

ENSEMBLE: Reconciling National Forecasts of Atmospheric Dispersion
 EOS: Earth Observing System
 EPA: Environmental Protection Agency
 EPHTN: Environmental Public Health Tracking Network
 ESA: European Space Agency
 ET: evapotranspiration
 ETM: Enhanced Thematic Mapper
 FAO: Food and Agriculture Organization of the United Nations
 FLAMBÉ: Fire Locating and Modeling of Burning Emissions
 FRAPPÉ: Front Range Air Pollution and Photochemistry Experiment
 FRP: fire radiative power
 FY: fiscal year
 GDAS: Global Data Assimilation System
 GEIS: Global Emerging Infections Surveillance and Response System
 GEO: Group on Earth Observations
 GEOS-Chem: Goddard Earth Observing System-Chemistry
 GFDL: Geophysical Fluid Dynamics Laboratory
 GFS: Global Forecast System
 GIS: geographic information system
 GISS: Goddard Institute for Space Studies
 GLDAS: Global Land Data Assimilation System
 GOES: Geostationary Operational Environmental Satellite
 GOME: Global Ozone Monitoring Experiment
 GPCP: Global Precipitation Climatology Project
 HBM: hierarchical Bayesian model
 IASI: Infrared Atmospheric Sounding Interferometer
 I-HEAT: Internet-based Heat Evaluation and Assessment Tool
 IPCC: Intergovernmental Panel on Climate Change
 ISES: International Society of Exposure Science
 ISORROPIA: thermodynamic equilibrium model
 ISPRS: International Society for Photogrammetry and Remote Sensing
 JRC: Joint Research Center of the European Commission
 LANCE: Land Atmosphere Near real-time Capability for EOS
 LiDAR: Light Detection And Ranging
 LNOM: Lightning NO_x-production Model
 LST: land surface temperature
 LT: lower troposphere
 MARAMA: Mid-Atlantic Regional Air Management Association
 MARKAL: MARKET Allocation
 MATCH: Metadata Access Tool for Climate and Health
 MDE: Maryland Department of the Environment
 MEGAN: Model of Emissions of Gases and Aerosols from Nature
 MERIS: MEdium Resolution Imaging Spectrometer
 MERIT: Meningitis Environmental Risk Information Technologies
 MISR: Multi-angle Imaging SpectroRadiometer
 MM5: Fifth-generation Pennsylvania State University/NCAR Mesoscale Model

MODIS: Moderate Resolution Imaging Spectroradiometer
 MOPITT: Measurements of Pollution in the Troposphere
 MOZART-4: Model for Ozone and Related Chemical Tracers, version 4
 NAAPS: Navy Aerosol Analysis and Prediction System
 NAAQS: National Ambient Air Quality Standards
 NAAQS: National Ambient Air Quality Standards
 NAM: North American Mesoscale
 NAQFC: National Air Quality Forecasting Capability
 NASA: National Aeronautics and Space Administration
 NCAR: National Center for Atmospheric Research
 NDVI: Normalized Difference Vegetation Index
 NEI: National Emissions Inventory
 NESDIS: National Environmental Satellite, Data, and Information Service
 NGO: nongovernmental organization
 NLCD: National Land Cover Data
 NLDAS: North American Land Data Assimilation System
 NLDN: National Lightning Detection Network
 NOAA: National Oceanic and Atmospheric Administration
 NPP: National Polar-orbiting Partnership
 NPS: National Park Service
 NSF: National Science Foundation
 NRL: Naval Research Laboratory
 NWS: National Weather Service
 OECD: Organization for Economic Cooperation and Development
 OGC: Open Geospatial Consortium
 OLCI: Ocean Land Color Instrument
 OMI: Ozone Monitoring Instrument
 OTC: Ozone Transport Commission
 OTC: Ozone Transport Commission
 PACE: Pre-Aerosol, Clouds, and ocean Ecosystem
 PBL: planetary boundary layer
 PI: principal investigator
 PL: production and loss
 PLOS: Public Library of Science
 PM: particulate matter
 PM2.5: fine particulate matter
 PREAM: Pollen REgional Atmospheric Model
 RAQC: Regional Air Quality Council
 RCP: Representative Concentration Pathway
 RCP: Representative Concentration Pathway
 REGARDS: REasons for Geographic And Racial Differences in Stroke
 SCIAMACHY: SCanning Imaging Absorption SpectroMeter for Atmospheric CHartography
 SEAC4RS: Studies of Emissions, Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys
 SI: stratospheric intrusion
 SIP: state implementation plan

SNODAS: Snow Data Assimilation System
SYRIS: Syndrome Reporting Information System
TCEQ: Texas Commission on Environmental Quality
TES: Tropospheric Emission Spectrometer
TMI: TRMM Microwave Imager
TMPA-RT: TRMM Multi-satellite Precipitation Analysis real-time
TRMM: Tropical Rainfall Measuring Mission
TVCD: tropospheric vertical column density
UNEP: United Nations Environment Program
USFS: United States Forest Service
USGS: United States Geological Survey
UT: upper troposphere
VIIRS: Visible Infrared Imaging Radiometer Suite
VOC: volatile organic compound
WASP: Weighted Anomaly Standardized Precipitation
WCS: Web Coverage Service
WELD: Web-enabled Landsat Data
WESTAR: Western States Air Resources Council
WFEIS: Wildland Fire Emissions Information System
WHIPS: Wisconsin Horizontal Interpolation Program for Satellites
WHO: World Health Organization
WMS: Web Map Service
WNV: West Nile virus
WONDER: Wide-ranging Online Data for Epidemiologic Research
WRF: Weather and Research Forecasting
WRF-Chem: Weather and Research Forecasting-Chemistry

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